Assessment of Altered Hydrologic Function, Dams, and Diversions Within the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon, Version 2

PREPARED FOR THE

NOAA FISHERIES, ARCATA OFFICE

BY

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Summary of October 2015 revisions to this report:
The initial final version of this report was completed on June 25, 2014.

Some of the analyses in this report will soon be published in a journal article:
Asarian, J.E. and J. Walker. *In press*. Long-Term Trends in Streamflow and Precipitation in Southwest Oregon and Northwest California, 1953-2012. *Journal of the American Water Resources Association*.

In the process of preparing that manuscript, I discovered two issues with the agricultural water use estimates that warranted revision of the 2014 report:
1) A calculation error resulted in under-estimation agricultural water use for some portions of the Klamath Basin. For mainstem Klamath River gages from the Klamath River at Keno Dam downstream to the Klamath River at Klamath, agricultural water use for most counties in Oregon was erroneously excluded. I have now corrected that error.
2) The agricultural water demand estimates for Oregon from HDR Inc. (2008) were not directly comparable to the evapotranspiration of applied water (ETAW) estimates for California, because the Oregon data included adjustments for conveyance efficiency and irrigation efficiency. Therefore, I have now applied an adjustment factor (multiply by 0.56) to the Oregon data to back-calculate ETAW values that are comparable to the California data.

I have revised the Methods section to describe the new method for estimating ETAW for Oregon. All results including figures and tables (Tables 11, Table 12, Table 14, Table 15, and Figure 15) affected by the calculation error and the new method for estimating ETAW in Oregon have now been revised in this October 2, 2015 version. As a result of these revisions, the agricultural and total water use changed for all gages whose watersheds include any part of Oregon. The ranks for total water use (in Tables 11, 14, and 15) changed for the following gages:
WF Illinois R (14375500): G to VG
Rogue R Grants Pass (14361500): P to F
Rogue R Agness (14372300): P to F
Rogue R At Raygold (14359000): P to F
Rogue R Dodge Bridge (14339000): G to VG
SF Rogue R S Prospect (14334700): G to VG
SF Big Butte Cr Nr Butte Falls (14335500): G to VG
Little Butte Cr At LakeCr (14346700): P to F
Klamath R Klamath (11530500): F to P
Klamath R Accr: Boyle - Keno (c11510700_11509500): VG to G
Williamson R Accr: Bl Sprg - SprgR - K Mrsh (c11502500_11493500_t1): G to VG
Sprague R: Williamson R - Sprague (c11502500_11501000): F to G

The calculation error and revised method did not affect streamflow trend analyses, final stress/threat ranks, or report appendices.

Suggested citation:
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EXECUTIVE SUMMARY

Summary
This report assesses hydrologic alteration, dams, and diversions within the Southern Oregon Northern California Coast (SONCC) Evolutionarily Significant Unit (ESU) of coho salmon. Streamflow, precipitation, and Geographic Information Systems (GIS) data were analyzed to calculate a series of quantitative indicators. Once indicators values were calculated, they were then rated on a four-category scale (i.e., very good, good, fair, poor), according to rules (i.e., category definitions) based on a combination of literature and professional judgment. The indicator ratings were then used in conjunction with other information to inform professional judgments, for each coho salmon population and life stage, of the rank (i.e., very high, high, medium, or low) of the stress of altered hydrologic function and the threat of dams and diversions. These ranks are the final products of this report and are now available for use in the recovery plan for SONCC coho salmon which is currently in development; however, the NMFS will allow recovery plan authors to use their professional judgment to over-ride these ranks. Recommended overall population-level ranks are presented in maps at the end of this Executive Summary.

The analysis included testing for long-term trends (1953-2012) in streamflow and precipitation, estimating diversions for residential and agricultural uses, and quantifying reservoir water storage. Results were summarized by stream gage and/or coho salmon population area. Few (6%) watersheds had statistically significant decreasing trends in annual precipitation, but September precipitation showed a statistically significant decline in 53% of watersheds. Summer base flows declined significantly in many streams, even after a model was used to account for the variability in streamflow cause by precipitation. Streams with very low human water use (i.e., extremely low human population density and little or no agriculture) were less likely to have a significant declining trend in summer flow; however, declines did occur in some streams in this category, apparently due to increased vegetation/forest evapotranspiration from some combination of climate change and/or change in forest stand structure/composition. The most pristine surface-runoff dominated watersheds within the ESU (i.e., those with very few diversions and relatively little landscape disturbance), such as Elder Creek (tributary to South Fork Eel River), Smith River, Chetco River, Salmon River, and tributaries to the Klamath River between Seiad Valley and Orleans, generally showed no decreases in summer flow once the variability due to precipitation was accounted for. Agricultural water use was greater than minimum 30-day average streamflow in some watersheds with large-scale irrigation including the Scott River, Shasta River, Bear Creek (tributary to Rogue River), Outlet Creek (tributary to Eel River), and to a lesser extent, parts of the upper Klamath River. Indoor/outdoor residential water use was only a small fraction of minimum 30-day average streamflow in nearly all gaged streams; however, even if human water use is only a relatively small percentage of summer streamflow within a larger watershed, many small streams within that larger watershed could still be periodically dried up by the instantaneous effects of multiple high-capacity pumps operating simultaneously, killing juvenile coho salmon and resulting in population-level effects.

Background

This report was prepared as part of NOAA National Marine Fisheries Services' (NMFS) development of an Endangered Species Act recovery plan for the SONCC coho salmon ESU. The January 2012 draft recovery plan identified summer flow as a key limiting factor for many populations of coho salmon within the ESU. Therefore, the NMFS Northern California Office recovery team places a high priority on improving the assessment of the stress and threat resulting from altered hydrologic function and dams and diversion. This report assesses the stress 'Altered Hydrologic Function' and the threat 'Dams and Diversions' for the coho salmon populations within the SONCC ESU. The first step was to assess the magnitude of hydrologic alteration within each of the population areas (i.e., the magnitude of the stress). The second step was to assess the causes of the alteration (i.e., the threats affecting the stress).

Assessing magnitude of hydrologic alteration

At least one long-term (i.e., at least 20 years, typically >50 years) stream gage dataset is available for 27 of the 41 populations within the ESU, including all but two core populations (Humboldt Bay tributaries, CA and Elk River, OR). Using stream gage data from the U.S. Geological Survey (USGS) and Oregon Department of Water Resources (OWRD), I assessed the long-term trends in various streamflow metrics (e.g., monthly flow, minimum 7-day average flows, timing of runoff, etc.). Precipitation has a strong effect on streamflow and could potentially confound the analysis of non-precipitation factors (e.g., land use changes) on streamflow. Therefore, to remove the effect of precipitation from the long-term trend in flow, I developed a regression model between API and monthly flow. Watersheds with gages were categorized by elevation (i.e., rain-dominated vs. snow-dominated) and geology (i.e., surface-dominated vs. groundwater dominated) using a peer-reviewed method to aid in interpretation of the results.

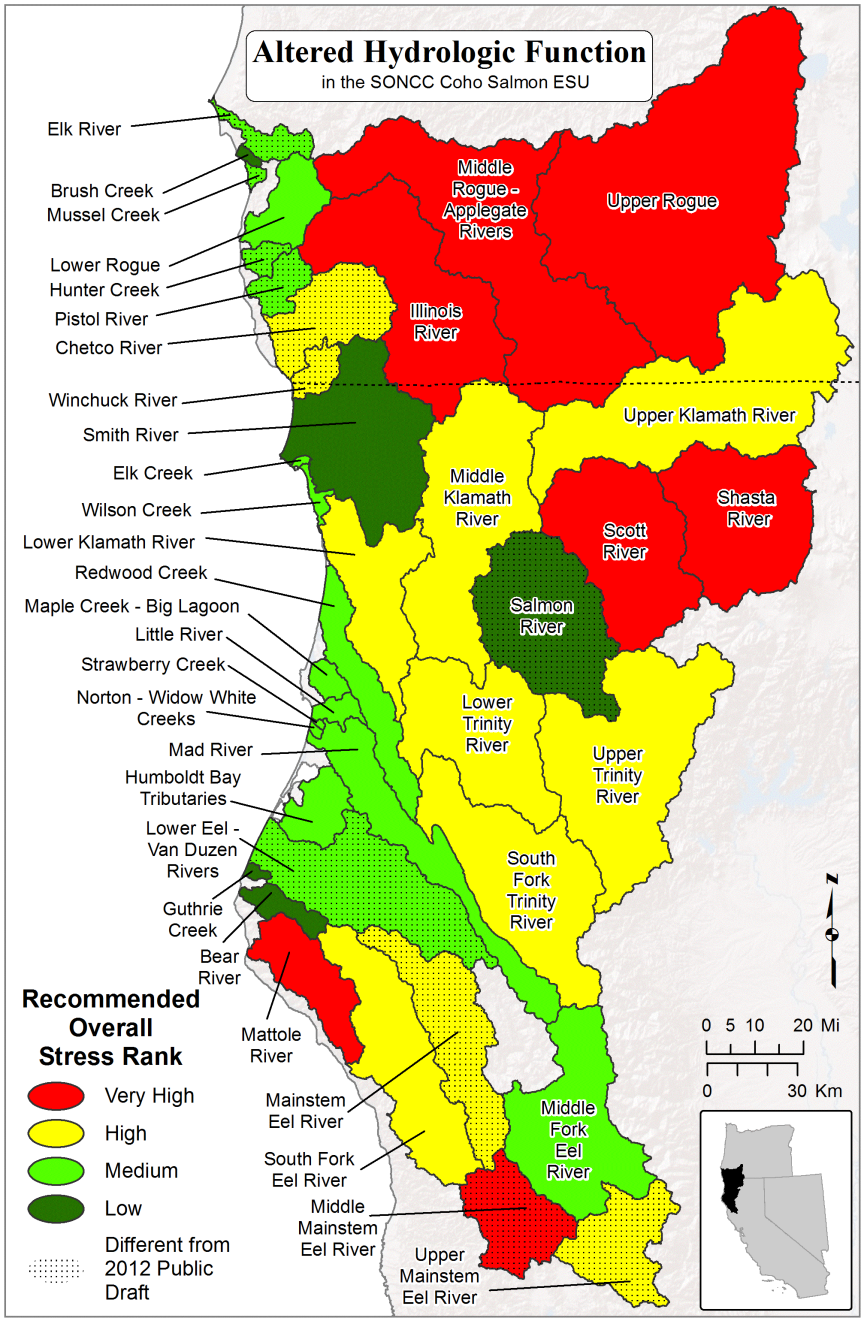
In most watersheds, intensive hydrologic and landscape alterations occurred prior to the establishment of long-term streamflow gages, which complicated the interpretation of results. Watersheds with a long history of major dams, large irrigated areas, significant human populations, or landscape alteration (e.g., timber harvest, road-building, wetland draining/filling, or floodplain disconnection)may have no detectable long-term trend in the streamflow gage data but still have significant hydrologic alteration. For example, the Shasta River at Yreka (gage 1151750 near the river's mouth) has no statistically significant long-term trend in August streamflow across either the 1953-2012 period that is the focus of this analysis nor the entire 1934-2012 period of record; however, median August flow for the period of record are only 33 cfs, equal to less than one quarter of the estimated unimpaired flow (i.e. if there were no diversions) of 140 cfs (Null et al. 2010), indicating significant alteration. Thus, some additional indicators (i.e., surrogates) of hydrologic alteration, not dependent on long-term flow data, were identified and calculated to identify the areas with longstanding hydrologic alteration. The additional indicators included estimated human water use as a percent of 30-day minimum flow as well as GIS-based indicators of hydrologic alteration: percent impervious surfaces, road density, percent of watershed area in agriculture, human population density, and reservoir storage as a percent of precipitation. The resulting indicator values were rated as either poor, fair, good, or very good according to the degree of hydrologic alteration, with category boundaries based on a combination of scientific literature, professional judgment, and frequency distributions.

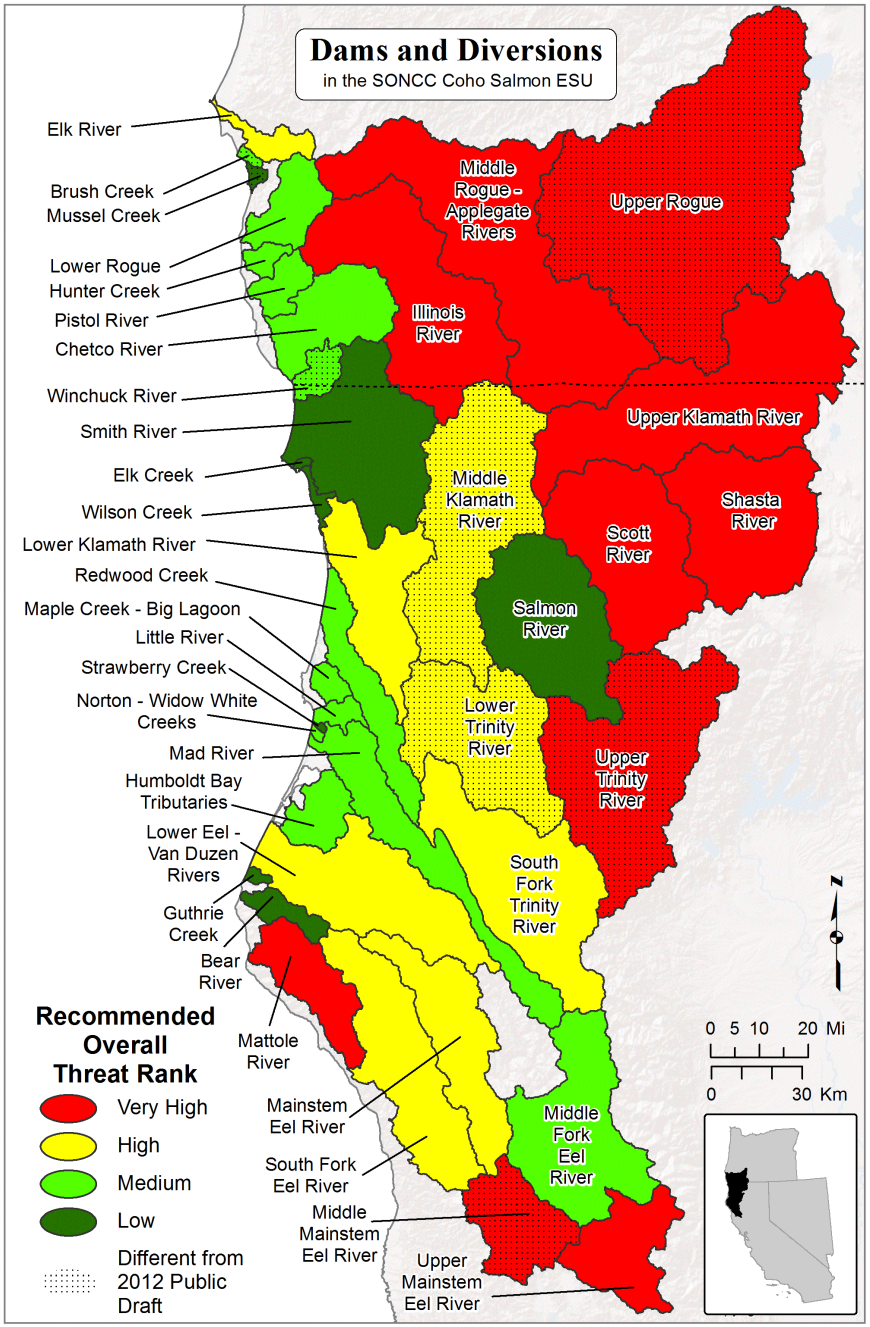
Some indicators were calculated at the geographic scale of an entire coho salmon population while others were calculated for the watershed area contributing to a stream gage. These two geographic scales are rarely identical and NMFS requires stresses and threats ranking in the recovery plan to be

determined at the geographic scale of an entire coho salmon population. Thus, professional judgment was used to combine the results of the two geographic scales of indicators with the best available information on stream hydrology to determine a stress rank (i.e., very high, high, medium, or low) for altered hydrologic function for each coho salmon population and life stage. The professional judgments also considered the findings of the ODFW (2008) expert panel and the public draft 2012 NMFS coho salmon recovery plan.

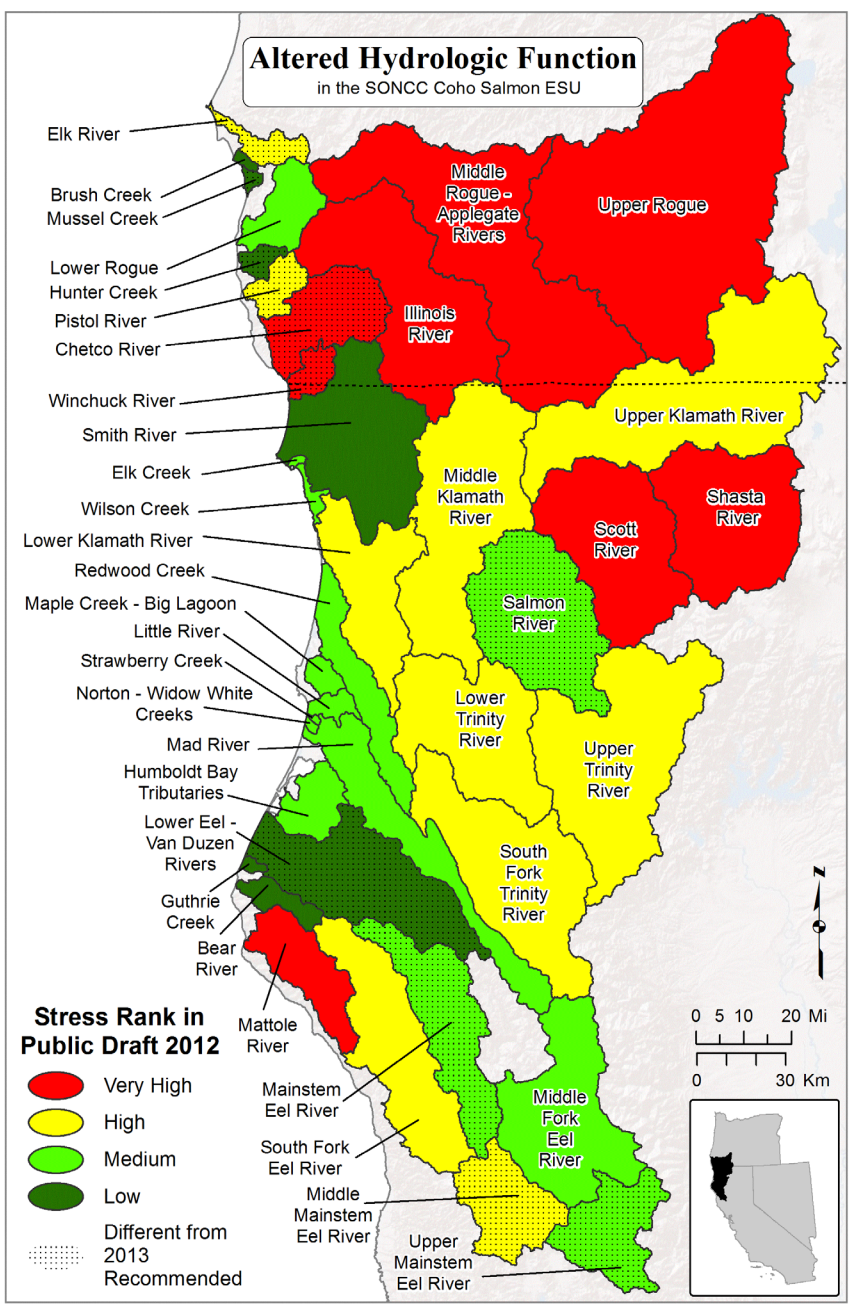
Assessing sources of hydrologic alteration, including the threat of dams and diversions
Residential water consumption was estimated by applying per-capita daily water consumption estimates from the California Department of Water Resources (CDWR) to block-level human population density from the U.S. Census. Annual agricultural water consumption estimates were obtained from CDWR and OWRD and used to estimate monthly agricultural water use by assuming water was evenly applied across a 6-month irrigation season. The combined sum of residential and agricultural water use was then compared relative to the average streamflow during the 30-day period of the year when streamflows are the lowest. While there is a relatively high degree of uncertainty in these estimates due to census undercounts in rural areas (including clandestine residences) and local variation in the per-capita water consumption, these estimates are currently the best available information.

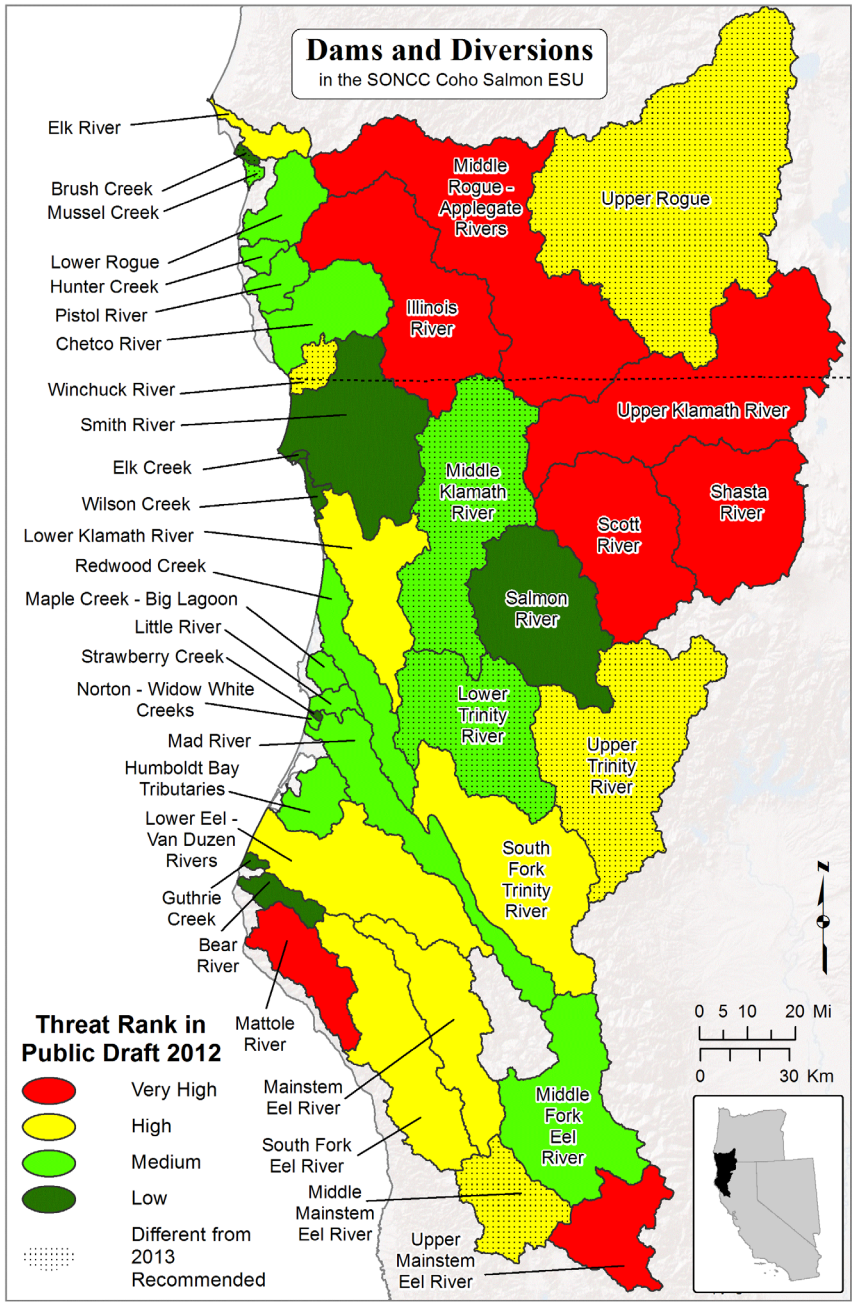
In addition to human water use, the following GIS-based indicators were used to assess the threat of dams and diversions and rated as very high, high, medium, or low: reservoir storage as a percent of precipitation, human density, and percent of watershed area in agriculture. Similar to the approach described for altered hydrologic function, professional judgment was used to determine a threat rank (i.e. very high, high, medium, or low) for dams and diversions for each coho salmon population and life stage.





Overall stress rank for altered hydrologic function (left map) and threat rank for dams and diversion (right map) recommended in this report for each coho salmon population in the SONCC ESU. Populations where ranks differ from those in the 2012 Public Draft of the Recovery Plan are marked with stiples.





Overall stress rank for altered hydrologic function (left map) and threat rank for dams and diversion (right map) in the 2012 Public Draft of the Recovery Plan for each coho salmon population in the SONCC ESU. Populations where ranks differ from those recommended in this report are marked with stiples.

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1 INTRODUCTION

1.1 DESCRIPTION OF STUDY AREA

The Southern Oregon Northern California Coast (SONCC) Evolutionarily Significant Unit (ESU) of coho salmon includes all populations of coho salmon in coastal streams from the Elk River near Cape Blanco, Oregon, through and including the Mattole River near Punta Gorda. The SONCC ESU spans two states (Oregon and California) and 13 counties (Coos, Douglas, Curry, Josephine, Jackson, Klamath, Del Norte, Siskiyou, Humboldt, Trinity, Mendocino, Lake, Glen).

1.2 BACKGROUND AND PURPOSE

NMFS is currently developing an Endangered Species Act recovery plan for the SONCC coho salmon ESU. In the January 2012 draft of the recovery plan for the ESU, the assessment of the stress 'Altered Hydrologic Function' and the threat 'Dams and Diversions' were based on professional judgment. In a limited number of populations, this judgment was informed by analyses/assessments conducted outside the recovery planning process. The assessment of this stress and threat in the January 2012 draft assigned a 'low' to 'very high' stress or threat rating, but there was no specific definition for these ratings. The draft recovery plan identified summer flow as a key limiting factor for many coho salmon population within the ESU, and thus it is a high priority of the NMFS Northern California Office to improve the assessment of this stress and threat.

This report describes a new approach to assessing the stress 'Altered Hydrologic Function' and the threat 'Dams and Diversions' for the populations within the ESU. This approach will result in stress- and threat-specific definitions for the low to very high ratings of this stress and threat, based on the best available scientific information.

1.3 EFFECT OF HYDROLOGIC ALTERATION ON COHO SALMON

Water is the most essential component of fish habitat. Inadequate flows can detrimentally affect coho salmon by decreasing summer rearing habitat and reducing access to spawning grounds. This assessment focuses primarily on summer flows because they have been identified by NMFS in the recovery plan as a limiting factor for many populations within the SONCC coho salmon ESU. Reduced summer flows can reduce growth and survival of coho salmon juveniles through several pathways, including: stream dewatering, increased water temperature, reduced habitat volume and quality, reduced food availability, and increased vulnerability to predation.

The most extreme case of reduced flow is stream dewatering, causing immediate mortality of any coho salmon rearing in the dry reach. While loss of surface flow can occur for prolonged durations, such as months, loss of surface flow can also occur on much shorter time scales such as hours or minutes. Small streams with multiple adjacent water diversions that operate simultaneously are particularly susceptible to running dry (Lancaster 2013) or experiencing rapid flow decreases (Deitch et al. 2009).

Coho salmon juveniles oversummer in freshwater and are particularly vulnerable to high summer water temperatures. Water temperatures can be strongly affected by the quantity of water in a stream, with effects varying by location and season according to site-specific factors. For example, the BasinTemp[1] water temperature model predicts that a 50% reduction in flow would cause

[1] BasinTemp model predicts water temperature for entire watersheds. It was developed by Stillwater Sciences (http://www.stillwatersci.com/tools.php?tid=25) for the South Fork Eel River TMDL. It integrates a solar radiation

maximum weekly average temperature (MWAT, the average temperature during the warmest 7-day period of the year) to increase as much as 2-3˚C in Bull Creek, a tributary to the South Fork Eel River, while a 50% increase in flow would decrease MWAT by a slightly lesser amount (Figure 1, Allen 2008). Similarly, the Heat Source model used in the development of the Scott River Total Maximum Daily Loads (TMDLs) predicts that a 50% decrease in groundwater accretion would increase peak summer water temperatures in mainstem Scott River by 2-3˚C, whereas a 50% increase would reduce water temperatures by as much as 2˚C (Figure 2, NCRWQCB 2005).

As flow decreases, so do the depth, volume, and complexity of pools where coho salmon juveniles over-summer (May and Lee 2004). Another potential result of low summer flow is loss of hydraulic connectivity in riffles (Magoulick and Kobza 2003). In such cases, pools become isolated from each other and drift of aquatic macroinvertebrates from riffles into pools is eliminated, reducing food availability for juvenile salmonids and hence reducing growth rates (Stillwater Sciences and Dietrich 2002, McBain and Trush 2012). Field experiments in a small Humboldt Bay stream found that even when hydraulic connectivity was maintained, reduced flow resulted in less invertebrate drift which dramatically reduced growth of rainbow trout (Harvey et al. 2006). With loss of connectivity, fish movement is restricted to single habitat units and they become more vulnerable to predation (Magoulick and Kobza 2003). Studies in a Washington stream found that juvenile coho that moved between habitat units grew faster than those who did not move (Kahler et al. 2001).

Increased flow (either total annual, spring or summer) results in increased smolt migration (Berggren and Filardo 1993, McCormick et al. 1998) or survival (Mathews and Olson 1980, Scarnecchia 1981, Giorgi 1993, Čada et al. 1994, Lawson et al. 2004). Berggren and Filardo (1993) found a significant correlation between average flow and smolt migration time in the Columbia River. Scarnecchia (1981) found a highly significant positive relationship between total stream flows and the rate of survival to the adult life stage for coho salmon in five Oregon rivers. Mathews and Olson (1980) documented a positive correlation between summer stream flow and adult coho salmon abundance. Coho salmon smolt production was positively correlated with summer flows in a coastal Washington stream (Beecher et al. 2010) and spring flows on the Oregon Coast (Lawson et al. 2004). Summer flow is an important explanatory variable of juvenile steelhead survival in tributaries of the Russian River (Granthan et al. 2012).

In addition to the relationship between flows and juvenile salmonid survival, flows can also affect juvenile salmonid growth. In studies on brook trout and juvenile Atlantic salmon, Davidson et al. (2010) and Xu et al. (2010) found that increased flow was generally associated with higher growth rates. Juvenile salmonids had 24 to 50 percent size reductions under low flow conditions (Davidson et al. 2010, Xu et al. 2010, Nislow and Armstrong 2012).

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model (which includes a channel network, digital elevation model, and tree-height model), an energy balance model, and a hydrologic model.

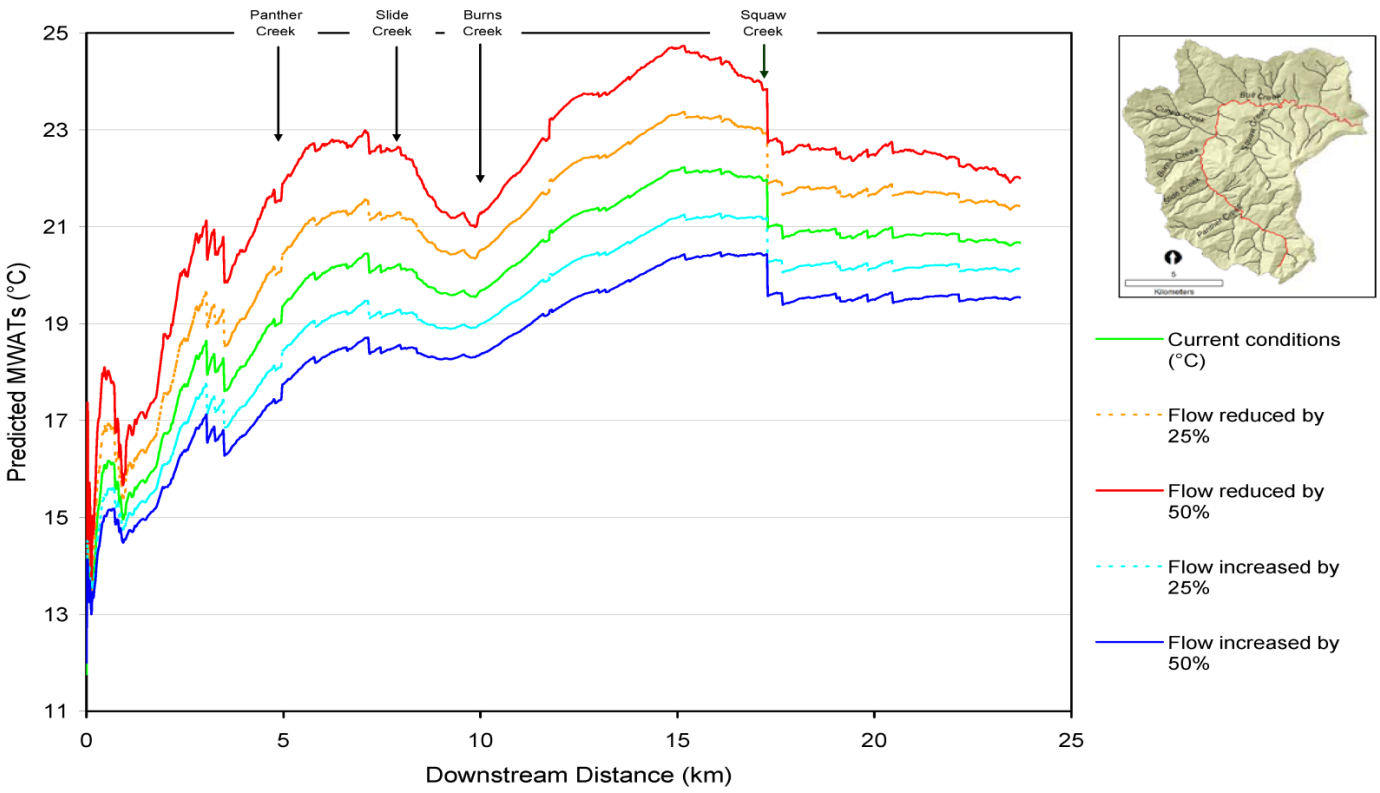

Figure 1. Effects of reducing (or increasing) flow by 25% and 50% on the thermal longitudinal profiles of Bull Creek (from Allen 2008).

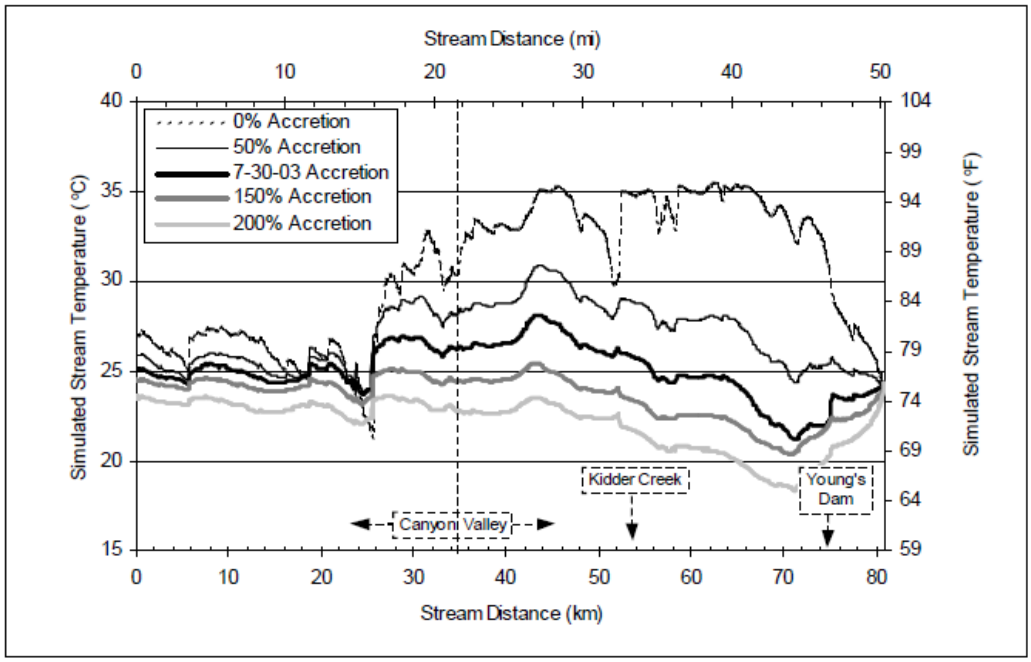

Figure 2. Longitudinal profiles of TMDL temperature modeling results quantifying effects of groundwater accretion, Scott River mainstem at 3:00pm, July 30, 2003. Figure 4.13 from the NCRWQCB (2005).

1.4 COMPARISON OF HYDROLOGIC ALTERATION ASSESSMENT METHODS IN THE PUBLIC DRAFT SONCC PLAN VERSUS NEW APPROACH

For the public draft of the SONCC plan, two qualitative indicators informed the assessment of altered hydrologic function stress (Table 1). These indicators were provided the U.S. Forest Service and Oregon Department of Fish and Wildlife. NMFS staff considered these indicators, as well as any other information available, when making their final professional judgments for the altered hydrologic function rating.

Table 1. Qualitative indicators for altered hydrologic function stress in public draft SONCC plan.

Indicator	Poor	Fair	Good	Very Good
Flow Restoration Needs (ODFW judgment)*	3.5-4	2.5-3.5	1.5-2.5	1-1.5
Water Quantity/Flow Regime (USFS judgment)**	Altered	Partially Altered		Unaltered

* This indicator was only available for populations in Oregon.
** This indicator was only provided by USFS for the portions of the population area that had significant USFS ownership and were in California, so 1) it was not available for some populations (i.e., in Oregon or no USFS land), and 2) it was not representative of the entire area for some populations (i.e., those where USFS land covered only part of the population area).

The proposed new indicators for altered hydrologic function, including the definitions of ratings are listed in Table 2.

1.5 COMPARISON OF DAMS/DIVERSIONS ASSESSMENT METHODS IN PUBLIC DRAFT SONCC PLAN VERSUS NEW APPROACH

For the public draft of the SONCC plan, no indicators were used to assess the threat of dams and diversions. Threat rankings were based solely on professional judgment by NMFS staff.

The proposed new indicators for dams/diversions, including the definitions of ratings are listed in Table 3. Two indicators used for the altered hydrologic function threat (significant trends in minimum 30-day average flow and average September flow with the effect of precipitation accounted for) were not used to inform the dams and diversions threat because those indicators can be strongly affected by factors other than dams and diversions. For example, the trend in average September flow with the effect of precipitation accounted for is affected by long-term changes in vegetation/forest evapotranspiration due to climate changes (i.e. air temperature, wind, humidity, or precipitation shifting from snow to rain) and/or change in forest stand structure/composition. In addition to the factors mentioned in the previous sentence, the trend in minimum 30-day average flow is also affected by long-term changes in precipitation timing and magnitude.

Table 2. Recommended quantitative indicators for altered hydrologic function stress in the new proposed approach.

Indicator	Poor	Fair	Good	Very Good	Notes on Rating Source	Coho Salmon Life Stage Affected	Geographic Scale of Results and Where Results Are Presented
Reservoir storage as a % of precipitation	>15%	>5-15%	0.5-5%	<0.5%	Best professional judgment	All	By gage: Table 7, Figure 16 By population: Table 13
Statistically significant trend* in minimum 30-day average flow	>1%/yr decrease	>0.5-1.0%/yr decrease	0-0.5%/yr decrease	Increase or no significant trend	Best professional judgment	Juvenile	By gage: Table 8, Figure 11
Statistically significant trend* in average September flow with the effect of precipitation accounted for	>1%/yr decrease	>0.5-1.0%/yr decrease	0-0.5%/yr decrease	Increase or no significant trend	Best professional judgment	Juvenile	By gage: Table 8, Figure 14
Human water use (domestic plus agricultural) as a % of 30-day minimum flow	>50%	>20-50%	2-20%	<2%	Best professional judgment	Juvenile	By gage: Table 11, Figure 15
Human population density	>25 persons/ km.^{2}	>5-25 persons/ km.^{2}	1-5 persons/ km.^{2}	<1 persons/ km.^{2}	Approximate quartiles	All	By population: Table 13
% of watershed area in agriculture	>10%	>5-10%	2-5%	<2%	Kier Associates and NMFS (2008)	All	By population: Table 13
% impervious surfaces	>25%	>10-25%	5-10%	<5%	Kier Associates and NMFS (2008)	All	By population: Table 13
Road density	>3.0 mi/mi^2	>2.5-3.0 mi/mi^2	1.6-2.5 mi/mi^2	<1.6 mi/mi^2	Kier Associates and NMFS (2008)	All	By population: Table 13

* Trends evaluated for the period 1953-2012. Percents are relative to the median of the entire period, not the start of period, so total change for the period would be the per-year trend slope multiplied by 30 (half the 60-year period). Threshold of statistical significance is $p < 0.10$.

Table 3. Recommended quantitative indicators for dams/diversions threat in the new proposed approach.

Indicator	Poor	Fair	Good	Very Good	Notes on Rating Source	Coho Salmon Life Stage Affected	Geographic Scale of Results and Where Are Results Presented?
% of coho salmon habitat inaccessible due to dams	>40%	>15-40%	1-15%	<1%	Best professional judgment	All	By population: Table 13
Reservoir storage as a % of precipitation	>15%	>5-15%	0.5-5%	<0.5%	Best professional judgment	All	By Gage: Table 7, Figure 16 By population: Table 13
Domestic water use as a % of 30-day minimum flow	>50%	>20-50%	2-20%	<2%	Best professional judgment	Juvenile	By gage: Table 11, Figure 15
Agricultural water use as a % of 30-day minimum flow							
Human population density	>25 persons/km.^{2}	>5-25 persons/km.^{2}	1-5 persons/km.^{2}	<1 persons/km.^{2}	Approximate quartiles	All	By population: Table 13
% of watershed area in agriculture	>10%	>5-10%	2-5%	<2%	Kier Associates and NMFS (2008)	All	By population: Table 13

1.6 PREVIOUS QUANTITATIVE ANALYSES OF HYDROLOGIC AND METEORLOGIC TRENDS WITHIN THE SONCC COHO SALMON ESU

There have been several previous analyses of long-term hydrologic and meteorlogic trends within and nearby the SONCC coho salmon ESU. Because the intent was on detecting trends due to climate change, these studies focused primarily on assessing streams less impacted by human land use, flow regulation, and water diversions. In contrast, this report aims to assess trends in streamflow in all streams with long-term datasets, regardless of their degree of human alteration.

Madej (2011) evaluated trends in climate, streamflow, and stream temperature along California's north coast from the Oregon border south to the Golden Gate. Madej (2011) found that average stream temperatures in Redwood National Park showed a statistically significant ($p < 0.10$) increase for the months of January, April, and November between 1895 and 2007, and at sites further south there were increases in additional months. Across the available periods of record, statistically significant ($p < 0.10$) decreases in 7-day low flows were detected at Redwood Creek at Orick, Mattole River at Petrolia, Van Duzen River at Bridgeville , South Fork Eel River at Leggett, Lacks Creek (tributary to Redwood Creek), Elder Creek near Branscomb, and Redwood Creek at O'Kane (Highway 299 bridge) (Madej 2011)[2].

Chang et al. (2012) evaluated trends in monthly streamflow, 7-day low flow, and timing of runoff in unregulated streams without notable diversions in Oregon, Washington, Idaho, and western Montana for the years 1958 to 2008. Findings included significant declines in absolute September streamflow at most stations. Relative (i.e., as a percent of annual flow), but not absolute, March streamflow increased at most streams with elevations over 1,000 m dominated by surface runoff (i.e., not groundwater). Most groundwater-dominated gages exhibited significant positive correlations between September absolute streamflow and April 1 snow water equivalent, while most (62%) surface-dominated gages did not. The Sprague River was the stream in the Chang et al. (2012) study that was geographically closest to the SONCC coho salmon ESU (it is located in the Upper Klamath Basin and although its water eventually flows into the Klamath River, it is upstream of the ESU boundary). Significant trends detected for at least one of the two Sprague River gages were: increasing relative March and April streamflow; decreasing relative streamflow in June, July and August; decreasing absolute July-December streamflow; and decreasing 7-day average low-flow (Chang et al. 2012).

Mayer and Naman (2011) analyzed 25 gages in unregulated streams in the Klamath Basin and adjacent areas and found that the response of streamflows to climate change from 1945 to 2007 varied according to geology and elevation. Warmer winter temperatures and associated reduced snowpack resulted in earlier runoff timing in both snowmelt and groundwater basins (Mayer and Naman 2011). Streams with groundwater-dominated runoff had much greater absolute (i.e., cfs) summer flow declines than streams dominated by surface runoff, although on a relative basis (i.e., percent) the declines were greater in surface runoff dominated streams. As a result, summer inflow to Upper Klamath Lake declined. In streams dominated by surface runoff, December flow increased and January, February, and March flow declined, mirroring trends in precipitation. October and November flows also declined from 1945 to 2007 in rain-dominated streams despite a

[2] Trends not significant at: Bull Creek near Weott, Eel River at Scotia, Little River near Trinidad, Mad River near Arcata, and Smith River at Crescent City.

lack of declining trend in November precipitation[3], a trend which the authors noted could potentially be due to warmer summer temperatures increasing evapotranspiration and decreasing soil moisture, slowing down fall recharge.

2 METHODS

2.1 SUMMARY OF METHODS

The final products of this report are the stress ranks for "altered hydrologic function" and threat ranks for "dams and diversions" for each coho salmon population and life stage. These ranks (i.e., very high, high, medium, or low) are professional judgments that are informed by a wide variety of information and detailed analyses, as summarized in Figure 3. A description of the judgment process is provided in section 2.10 (Determining Population-Level Stress and Threat Ranks).

Various data sources were used to calculate indicators of the magnitude of the hydrologic alteration as well as other effects of dams and diversions such as fish passage barriers. Some indicators were relatively simple to calculate while others required a series of complicated analytical steps. The data sources and calculation methods for each indicator are summarized in a diagram (Figure 4) and details are included in sections 2.2 through 2.9 below. After indicators values were calculated, they were then rated on a four-category scale (very good, good, fair, poor), according to rules (i.e., category definitions) based on a combination of literature and professional judgment. Besides the indicators listed in Figure 4, supplemental analyses of streamflow and precipitation were also conducted and are presented in this report; however, these were only tangentially considered in the judgment process.

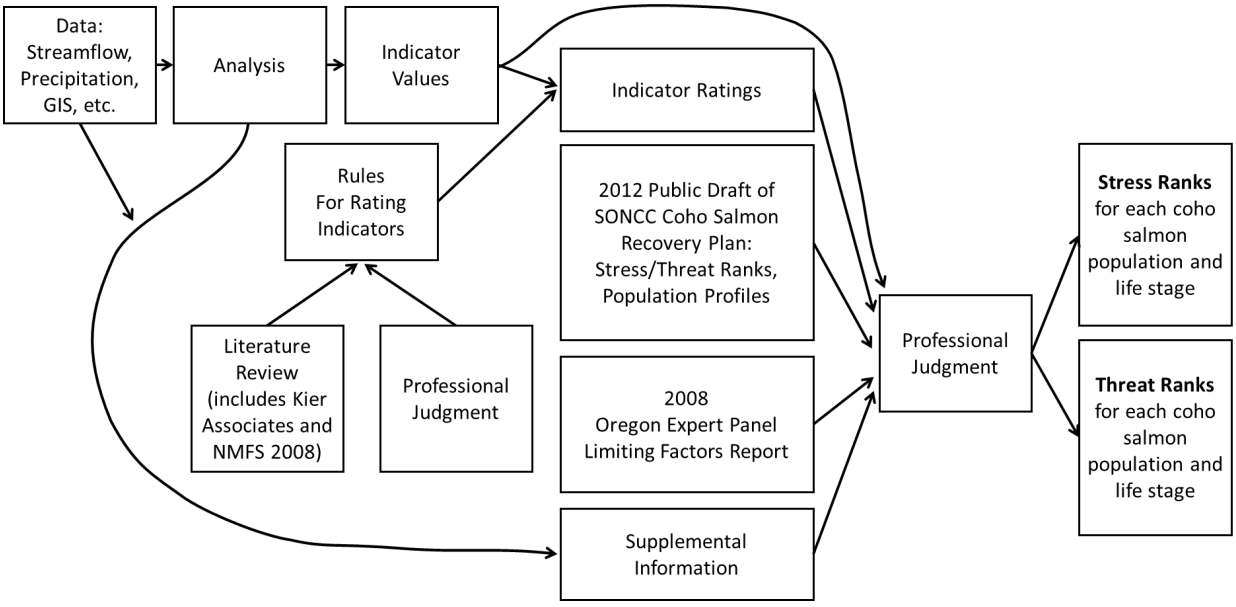
Data: Streamflow, Precipitation, GIS, etc.
Analysis
Indicator Values
Indicator Ratings
Rules For Rating Indicators
2012 Public Draft of SONCC Coho Salmon Recovery Plan: Stress/Threat Ranks, Population Profiles
Literature Review (includes Kier Associates and NMFS 2008)
Professional Judgment
2008 Oregon Expert Panel Limiting Factors Report
Supplemental Information
Professional Judgment
Stress Ranks for each coho salmon population and life stage
Threat Ranks for each coho salmon population and life stage

Figure 3. Summary of the process used to inform professional judgments and derive stress and threat ranks.

[3] Mayer and Naman (2011) did not note whether there were significant declines in October precipitation from 1945 to 2007. There was no significant trend in October precipitation for 1953-2012 at any sites within the SONCC ESU (see section 3.1 Long-Term Trends in Streamflow and Precipitation).

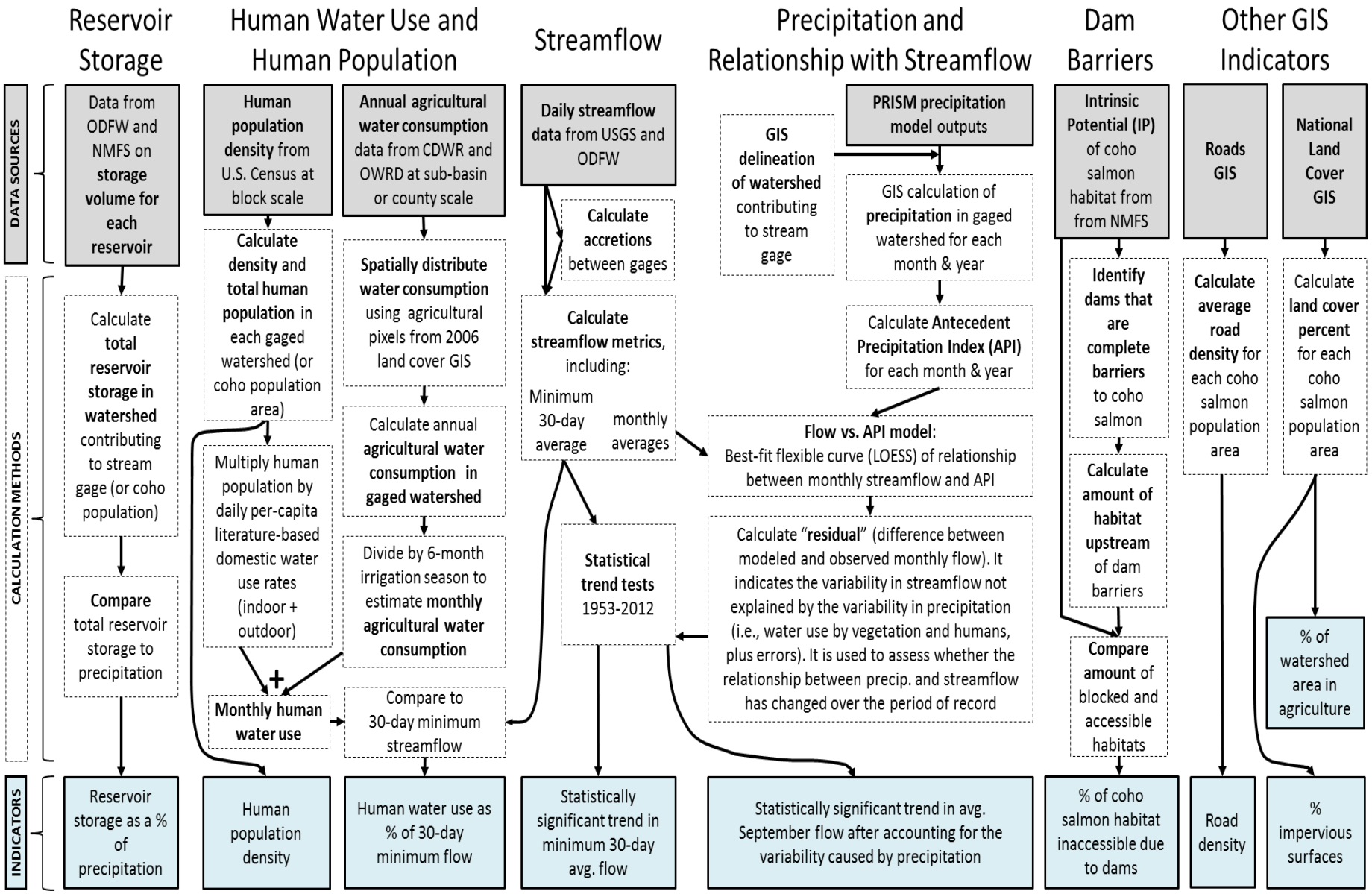
Reservoir Storage
Human Water Use and Human Population
Streamflow
Precipitation and Relationship with Streamflow
Dam Barriers
Other GIS Indicators
DATA SOURCES
CALCULATION METHODS
INDICATORS
Data from ODFW and NMFS on storage volume for each reservoir
Human population density from U.S. Census at block scale
Annual agricultural water consumption data from CDWR and OWRD at sub-basin or county scale
Daily streamflow data from USGS and ODFW
GIS delineation of watershed contributing to stream gage
PRISM precipitation model outputs
Intrinsic Potential (IP) of coho salmon habitat from from NMFS
Roads GIS
National Land Cover GIS
Calculate total reservoir storage in watershed contributing to stream gage (or coho population)
Calculate density and total human population in each gaged watershed (or coho population area)
Spatially distribute water consumption using agricultural pixels from 2006 land cover GIS
Calculate accretions between gages
GIS calculation of precipitation in gaged watershed for each month & year
Identify dams that are complete barriers to coho salmon
Calculate average road density for each coho salmon population area
Calculate land cover percent for each coho salmon population area
Calculate streamflow metrics, including:
Minimum 30-day average
monthly averages
Calculate Antecedent Precipitation Index (API) for each month & year
Multiply human population by daily per-capita literature-based domestic water use rates (indoor + outdoor)
Calculate annual agricultural water consumption in gaged watershed
Flow vs. API model:
Best-fit flexible curve (LOESS) of relationship between monthly streamflow and API
Calculate amount of habitat upstream of dam barriers
Compare total reservoir storage to precipitation
Divide by 6-month irrigation season to estimate monthly agricultural water consumption
Statistical trend tests 1953-2012
Calculate "residual" (difference between modeled and observed monthly flow). It indicates the variability in streamflow not explained by the variability in precipitation (i.e., water use by vegetation and humans, plus errors). It is used to assess whether the relationship between precip. and streamflow has changed over the period of record
% of watershed area in agriculture
Monthly human water use
Compare to 30-day minimum streamflow
Compare amount of blocked and accessible habitats
Reservoir storage as a % of precipitation
Human population density
Human water use as % of 30-day minimum flow
Statistically significant trend in minimum 30-day avg. flow
Statistically significant trend in avg. September flow after accounting for the variability caused by precipitation
% of coho salmon habitat inaccessible due to dams
Road density
% impervious surfaces

Figure 4. Diagram summarizing the data sources (gray boxes at top) and calculation methods (boxes in middle) used for each indicator (blue boxes at bottom).

2.2 STREAMFLOW

2.2.1 Data Sources

There are 92 flow gages with multiple decades of data in the range of the SONCC coho salmon ESU, but not all are currently in operation (Figure 5, Table 4). Some gages in the Rogue, Klamath, Trinity, Mad and Eel River basins that are located above dams or natural impassable barriers were still included in the analysis because their water flows downstream into coho salmon habitat. Gages in the Upper Klamath Basin upstream from the ESU boundary[4] were included in the analysis for the same reason. The primary dataset is the U.S. Geological Survey (USGS) National Water Information System (NWIS)[5] supplemented by additional data from the Oregon Water Resources Department (OWRD)[6]. Most of the gages are on the larger rivers, while some are in smaller tributaries. USGS gages with long-term (or currently operating) datasets were identified through the USGS GAGES-II project (Falcone et al. 2010, Falcone 2011). A small amount of additional gage data available from the National Park Service[7] and University of California[8] were not included in the analysis due to time constraints and data quality issues.

2.2.2 Basin Delineation

Geographic Information Systems (GIS) files from the GAGES-II dataset (Falcone 2011) included polygons for the catchment areas contributing to 87 of the 92 gages. The contributing areas for the remaining five gages were delineated using an NHDPlus Version 2 digital elevation model[9] and ArcGIS software.

2.2.3 Estimated Accretions Between Gages

Some river basins have multiple gages, allowing for the calculation of accretions between gages. The calculated accretion represents the net contributions of all tributaries and springs, minus any diversions.

Because they are derived from multiple (two to four) gages, the calculated accretions also inherently include the combined measurement error of all the component gages and are therefore substantially less accurate than flows measured at individual gages. Interpretations of accretion calculations must take into account this decreased accuracy. Despite the increased uncertainty, the 32 calculated accretions provide valuable data to supplement the relatively sparse network of streamflow gages within the study area (Table 4, Table 5). These accretions are calculated as the downstream flow minus the upstream flow minus any additional gaged tributaries. The accretions were calculated on a daily basis and then smoothed with a 7-day average to reduce the frequency of negative values.

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[4] The upstream extent of the ESU in the Klamath Basin is Spencer Creek near the Oregon/California border.

[5] NWIS data (http://waterdata.usgs.gov/nwis) were downloaded using the NWIS Snapshot tool (http://txpub.usgs.gov/snapshot/), which allows download of the entire daily period of record for many sites into a single database table.

[6] OWRD data downloaded from http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/. After completing the data analyses I found additional data for discontinued gages (e.g., station 14327250 Elk River) are available at: http://apps.wrd.state.or.us/apps/sw/hydro_report/ but it was too late to utilize these additional data.

[7] National Park Service operates several gages in Redwood National Park (Madej 2011), including two on Prairie Creek, for evaluating sediment production during winter high-flows, but quality control during the summer was low so those data cannot reliably be used for evaluating long-term trends in summer baseflow without first conducting extensive QAQC that was outside the scope of this report.

[8] In 1997, the University of California resumed data collection at the SF Eel near Branscomb gage that USGS operated from1947-1970 (http://angelo.berkeley.edu/angelo/research/data/meteorological-data/) but there are intermittent gaps in the dataset that would need to be estimated prior to use.

[9] http://www.horizon-systems.com/nhdplus/

Negative values can result from a number of factors including: measurement error, water diversions, and downstream transit of high flood peaks, as well as change in reservoir water storage for accretions with reservoirs between the gages[10].

2.2.4 Watershed Classification

Using criteria adapted from Mayer and Naman (2011)[11], gaged watersheds were stratified (classified) into four categories: surface-dominated rain basins, surface-dominated rain-snow basins, surface-dominated snowmelt basins, and groundwater-dominated basins. Surface versus groundwater was differentiated by modified base flow index (long-term average of the ratio of the annual 7-day average lowest daily flow to the annual mean daily flow). Rain, rain-snowmelt, and snowmelt were differentiated by elevation and streamflow centroid (i.e., the date by which 50 percent of the runoff in a water year has occurred; also known as center timing of streamflow, CT). Stratification is necessary because these groups could react very differently to changes in climate and vegetation and so in many cases should be analyzed separately (otherwise the variation between groups would obscure patterns that might otherwise be observable).

2.2.5 Flow Metrics for Trend Analysis

Key streamflow metrics were selected based on a review of previous hydrologic analyses (Poff 1996, Madej 2011, Mayer and Naman 2011, Chang et al. 2012) and calculated for each gage and year, including: minimum flow, the minimum 7-day average flow, minimum 30-day average flow, minimum 90-day average flow, average flow for each month, annual mean flow, and streamflow centroid. Minimum flow and minimum 7-day average flow were not calculated for accretions between gages due to the increased uncertainty at shorter time scales. Metrics were calculated using a combination of software: Microsoft Access, Microsoft Excel, Systat, and R.

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[10] The only reservoirs likely to substantially affect the accretion calculations are those on the mainstem Klamath River. J.C. Boyle Reservoir has a hydraulic retention time (HRT) of only 1-2 days. Copco 1 and Iron Gate Reservoirs are larger but are generally maintained at a relatively high and constant water level to maximize head for hydroelectric generation (they are generally not used to transfer water from one month to another). There are other larger reservoirs within the study area, but gages above and below those reservoirs were not used in accretion calculations.

[11] Mayer and Naman (2011) did not have a category for surface-dominated rain-snow basins, possibly because their study did not include the largest basins (maximum drainage area 9,399 km^2 vs. 40,912 km^2 in this report) that are strongly influenced by both rain and snow. Groundwater-dominated basins are defined in this report as base flow index > 25. Surface runoff-dominated basin is defined in this report as base flow index < 25. Snow basins: mean elevation >1200 m, and CT in or after mid-March. Rain-snow basins: max elevation >2000m, mean elevation <1200m, and CT in or before mid-March. Rain basins: mean elevation < 1200m, max elevation < 2000m, and CT in or before mid-March. Some professional judgment was applied for classification, because dams and water diversions affect base flow index and streamflow centroid (and elevation for the area contributing to accretions between gages was estimated not calculated).

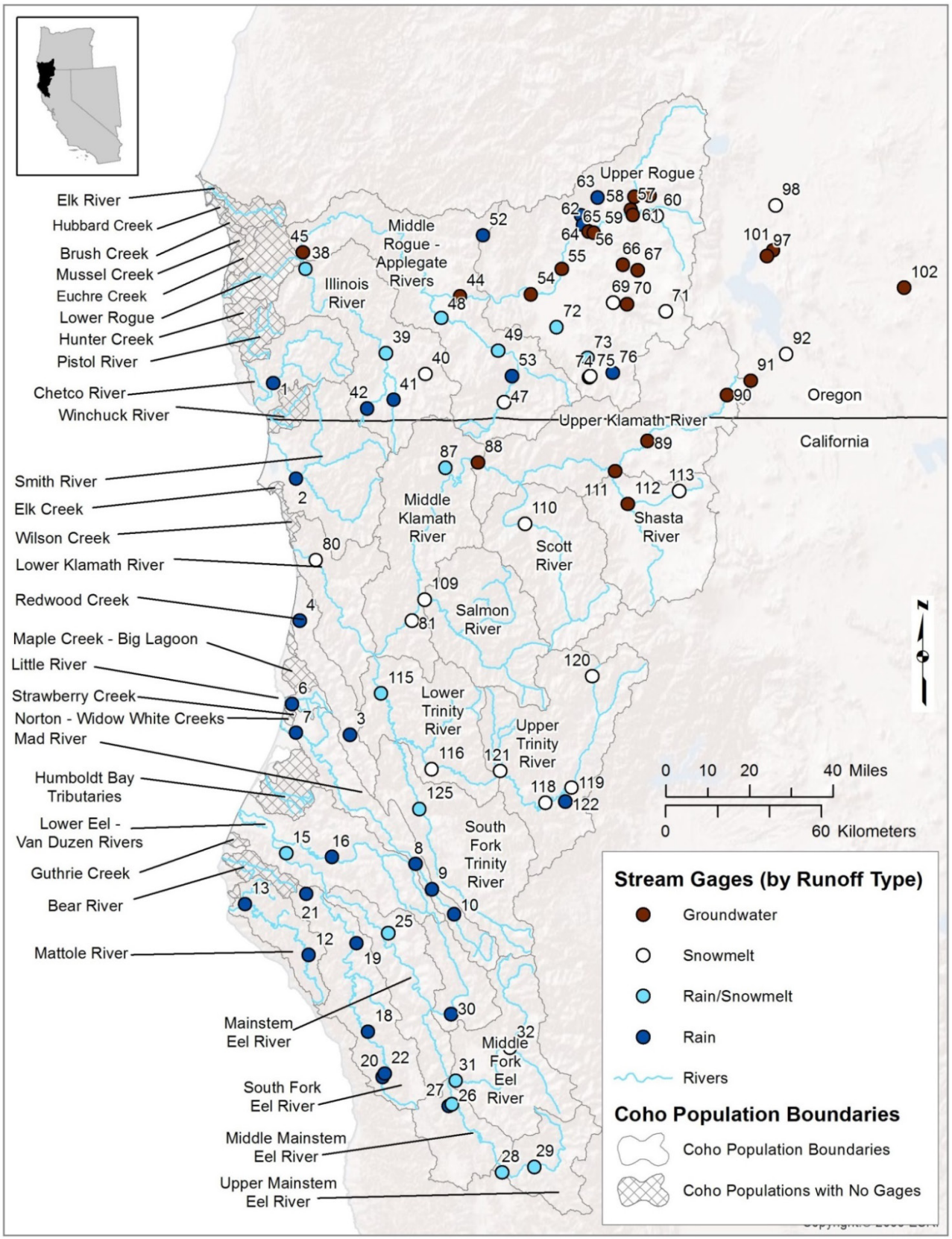

Figure 5. Map of streamflow gages used in hydrologic analysis overlaid on coho salmon populations and rivers. Gages are color-coded according to their runoff type (geology and elevation). Numeric labels correspond to 'map label' column of Table 4. Some Upper Klamath Basin gages are located upstream of the ESU boundary, but their water flows downstream into the ESU.

Table 4. List of streamflow gages used in hydrologic analysis. Map label column refers to Figure 5. Key to runoff types: G = groundwater, S = snowmelt, R/S = rain/snowmelt, R = rain. Key to hydrologic regulation ratings: 1= reservoir storage volume is 0-0.5% of precipitation, 2 = 0.5-5%, 3 = >5-15%, 4 = >15%. Trend column denotes time period(s) used for trend analysis (see section 2.5 for additional explanation): N = none, Y1= 1953-2012 and period of record, Y2 = period of record only due to insufficient 1953-2012 data [results only in appendices]).

Map Label	Gage Name (Gage Code) ["Accr" denotes estimated accretions between gages, see Table 5]	Complete Water Years of Gage Data	Basin Area (km^2)	Elevation (m)		Precip. (cm)	Runoff Type	Hydro. Regul.	Trend
				Mean	Max				
1	Chetco R (14400000)	1970-2012	703	671	1535	280	R	1	Y1
2	Smith R (11532500)	1932-2012	1578	772	1944	259	R	1	Y1
3	Redwood Cr Blue Lake (11481500)	1954-1958, 1973-1993, 1998-2012	175	893	1619	199	R	1	Y1
4	Redwood Cr Orick (11482500)	1912-1913, 1954-2012	718	558	1619	186	R	1	Y1
5	Redwood Cr Accr: Orick - 299 (c11482500_11481500)	1955-1957, 1974-1992, 1999-2012	543			182	R	1	Y1
6	Little R (11481200)	1956-2012	105	333	1027	165	R	1	Y1
7	Mad R Arcata (11481000)	1911-1913, 1951-2012	1257	800	1834	168	R	2	Y1
8	Mad R Forest Glen (11480500)	1954-1994	369	1103	1834	162	R	3	Y3
9	Mad R Bl Ruth Res (11480410)	1981-2011	313	1115	1834	163	R	3	Y3
10	Mad R Ab Ruth Res (11480390)	1981-2012	243	1130	1834	163	R	1	Y3
11	Mad R Accr: Arcata - Bl Ruth Res (c11481000_11480410)	1982-2010	944			170	R	1	N
12	Mattole R Ettersburg (11468900)	2002-2012	184	445	1116	186	R	1	N
13	Mattole R Petrolia (11469000)	1912-1913, 1951-2012	623	417	1221	195	R	1	Y1
14	Mattole R Accr: Petrolia - Ettersburg (c11469000_11468900)	2002-2011	439			199	R	1	N
15	Eel R Scotia (11477000)	1911-1914, 1917-2012	8062	786	2306	159	R/S	2	Y1
16	Van Duzen R (11478500)	1951-2012	572	923	1788	166	R	1	Y1
17	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)	1956-2012	1215			155	R	1	Y1
18	SF Eel R At Leggett (11475800)	1966-1994, 2000-2004, 2008-2012	642	626	1289	192	R	1	Y1
19	SF Eel R Nr Miranda (11476500)	1940-2012	1390	526	1289	185	R	1	Y1
20	SF Eel R Branscomb (11475500)	1947-1970	114	652	1281	200	R	1	N
21	Bull Cr (11476600)	1961-2012	72	473	1023	182	R	1	Y1
22	Elder Cr (11475560)	1968-2012	17	848	1277	247	R	1	Y1
23	SF Eel R Accr: Miranda - Leggett (c11476500_11475800)	1967-1994, 2001-2003, 2008-2012	748			179	R	1	Y1
25	Eel R Fort Seward (11475000)	1956-2012	5457	922	2306	154	R/S	2	Y1
26	Eel R Dos Rios (11472150)	1967-1994	1369	958	2140	137	R/S	3	N
27	Outlet Cr (11472200)	1957-1994	419	598	1042	143	R	2	Y3
28	Eel R Van Arsdale (11471500)	1911-1926, 1928-2012	904	1070	2140	138	R/S	3	Y1
29	Eel R Scott Dam (11470500)	1923-2012	750	1111	2140	138	R/S	3	Y1
30	NF Eel R (11474500)	1954-1976, 2002-2005	650	930	1873	170	R	1	N
31	MF Eel R (11473900)	1966-2012	1925	1122	2306	154	R/S	1	Y1
32	Black Butte R (11472900)	1959-1975, 2002-2005	419	1353	2249	155	S	1	N
33	Eel R Accr: Scotia - Van Ars (c11477000_11471500)	1912-1913, 1918-1926, 1929-2011	7158			162	R	1	Y1
34	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)	1941-2011	5768			156	R	1	Y1
35	Eel R Accr: Ft Sew - Van Ars - MF (c11475000_11471500_t1)	1967-2011	2628			159	R	1	Y1
36	Eel R Accr: Ft Sew - DRios - MF - Outl (c11475000_11472150_t1)	1968-1993	1744			168	R	1	N
37	Eel R Accr: Dos Rios - Van Ars (c11472150_11471500)	1968-1994	464			136	R	1	N
38	Illinois R Agness (14378200)	1961-1981	2545	816	2142	217	R/S	1	N
39	Illinois R Kerby (14377100)	1962-2012	985	880	2142	191	R/S	1	Y1

Map Label	Gage Name (Gage Code) ["Accr" denotes estimated accretions between gages, see Table 5]	Complete Water Years of Gage Data	Basin Area (km^2)	Elevation (m)		Precip. (cm)	Runoff Type	Hydro. Regul.	Trend
				Mean	Max				
40	Sucker Cr (14375100)	1966-1991, 1993-2012	217	1210	2142	151	S	1	Y1
41	EF Illinois R (14372500)	1928-1931, 1942-1996, 2001, 2007-2012	140	1116	1922	230	R	1	Y1
42	WF Illinois R (14375500)	1955-1985	110	771	1607	245	R	1	Y2
43	Illinois R Accr: Kerby - EF - Sucker Cr (c14377100_14372500_t1)	1967-1991, 1993-1995, 2007-2012	628			196	R/S	1	Y1
44	Rogue R Grants Pass (14361500)	1940-2012	6362	1006	2862	97	G	3	Y1
45	Rogue R Agness (14372300)	1961-2012	10197	928	2862	104	G	3	Y1
46	Rogue R Accr: Agness - Grants Pass (c14372300_14361500_t1)	1962-2012	2581			124	R/S	1	Y1
47	Applegate R Copper (14362000)	1939-2012	580	1294	2248	118	S	4	Y1
48	Applegate R Wilderville (14369500)	1939-1955, 1979-2012	1810	998	2248	95	R/S	3	Y2
49	Applegate R Applegate (14366000)	1939-2012	1253	1121	2248	97	R/S	3	Y1
50	Applegate R Accr: Wilderville - Applgt (c14369500_14366000)	1940-1954, 1979-2012	557			90	R	1	Y2
51	Applegate R Accr: Applgt - Copper (c14366000_14362000)	1940-2012	673			79	R/S	1	Y1
52	Grave Cr (14371500)	1945-1986, 1988	63	1053	1600	142	R	1	Y2
53	Star Gulch (14362250)	1984-2011	41	981	1531	83	R	1	N
54	Rogue R At Raygold (14359000)	1906-2012	5310	1073	2862	100	G	3	Y1
55	Rogue R Dodge Bridge (14339000)	1939-2012	3155	1186	2862	117	G	4	Y1
56	Rogue R Near Mcleod (14337600)	1966-2012	2438	1295	2862	122	G	4	Y1
57	Rogue R Blw Prospect (14330000)	1914-1930, 1969-2004, 2006-2012	986	1425	2457	137	G	1	Y1
58	Rogue R Abv Prospect (14328000)	1909-1910, 1924-1998	811	1476	2457	139	G	1	Y1
59	SF Rogue R S Prospect (14334700)	1969-1992	638	1434	2318	127	G	1	N
60	SF Rogue R Nr Prospect (14332000)	1925-1931, 1950-2012	217	1562	2261	124	S	1	Y1
61	Red Blanket Cr (14333500)	1934-1981	116	1593	2318	146	G	1	Y2
62	Elk Cr Trail (14338000)	1947-2005, 2007-2011	336	950	1758	118	R	1	Y1
63	Elk Cr Cascade Gorge (14337800)	1974-2000	205	1025	1758	125	R	1	N
64	WB Elk Cr Trail (14337870)	1974-1976, 1978-2000	40	920	1448	115	R	1	N
65	Big Butte Cr Near Mcleod (14337500)	1946-1957, 1968-2012	641	1076	2862	99	G	2	Y1
66	SF Big Butte Cr Nr Butte Falls (14335500)	1911, 1920-1922, 1926-1991	363	1224	2862	103	G	2	Y2
67	SF Big Butte Cr Ab Willow Cr (14335200)	1936-1950, 1952-1964, 1966-1992, 1994-1995, 1997-2000, 2008-2012	184	0	0	105	G	1	Y1
68	Little Butte Cr At LakeCr (14346700)	1973-1986, 2008-2012	548	0	0	95	S	3	N
69	SF Little Butte Cr Nr LakeCr (14341500)	1922-1957, 1961-1982	361	1313	2232	96	S	1	Y2
70	NF L Butte Cr Nr LakeCr (14343000)	1912, 1923, 1927, 1929-1964, 1966-1985, 2004-2005, 2007, 2009-2012	100	1395	2862	117	G	4	Y1
71	NF L Butte Cr At F L Nr LakeCr (14342500)	1917-1996, 2009-2012	43	1632	2862	130	S	4	Y1
72	Bear Cr At Medford (14357500)	1921-1981, 1985-2004, 2006-2012	722	1007	2281	71	R/S	3	Y1
73	Bear Cr Blw Ashland Cr (14354200)	1991-2012	456	1130	2281	75	R/S	4	N
74	WF Ashland Cr Near Ashland (14353000)	1925-1932, 1976-1982, 2003-2011	25	1555	2201	106	S	1	N
75	EF Ashland Cr Near Ashland (14353500)	1925-1932, 1976-1982, 2003-2011	21	1561	2281	97	S	1	N
76	Emigrant Cr Nr Ashland (14350000)	1925, 1942-1944, 1946, 1954-1955, 1957, 1959-1985	171	1108	1845	67	R	4	Y2
77	NF L Butte Cr Accr: Nr Lake Cr - Falls (c14343000_14342500)	1923, 1929-1964, 1966-1985, 2010-2012	57			106	G	1	Y2
78	Rogue R Accr: Raygold - Mcleod (c14359000_14337600)	1967-2012	2872			81	R/S	2	Y1
79	Rogue R Accr: Raygold - Dodge Br (c14359000_14339000)	1940-2012	2156			74	R	3	Y1
80	Klamath R Klamath (11530500)	1911-1926, 1951-1994, 1998-2012	40912	1317	4303	94	S	3	Y1
81	Klamath R Orleans (11523000)	1928-2012	31496	1395	4303	75	S	3	Y1

Map Label	Gage Name (Gage Code) ["Accr" denotes estimated accretions between gages, see Table 5]	Complete Water Years of Gage Data	Basin Area (km^2)	Elevation (m)		Precip. (cm)	Runoff Type	Hydro. Regul.	Trend
				Mean	Max				
82	Klamath R Accr: Klamath - Sei (c11530500_11520500)	1914-1924, 1953-1994, 1999-2012	13409			159	R/S	1	Y1[a]
83	Klamath R Accr: Klamath - Sei - SalmR (c11530500_11520500_t1)	1914, 1953-1994, 1999-2012	11466			161	R/S	1	Y1[a]
84	Klamath R Accr: Klam - Sei - SalmR - TrinR (c11530500_11520500_t2)	1953-1994, 1999-2012	4075			193	R/S	1	Y1[a]
85	Klamath R Accr: Klamath - Orl - TrinityR (c11530500_11523000_t1)	1952-1994, 1999-2012	2025			197	R	1	Y1
86	Klamath R Accr: Orl - Sei - SalmR (c11523000_11520500_t2)	1953-2012	2050			188	S	1	Y1
87	Indian C (11521500)	1958-2008, 2010-2012	310	1128	2149	193	R/S	1	Y1
88	Klamath R Seiad Valley (11520500)	1913-1925, 1952-2012	27503	1431	4303	62	G	3	Y1
89	Klamath R Iron Gate Dam (11516530)	1961-2012	21541	1489	2858	58	G	4	Y1
90	Klamath R JCB Pwrplnt (11510700)	1960-2012	18500	1502	2858	57	G	4	Y1
91	Klamath R Keno (11509500)	1905-1913, 1930-2012	18081	1503	2858	56	G	4	Y1
92	Link R Klamath Falls (11507500)	1962-2012	9787	1559	2858	69	S	4	Y1
93	Klamath R Accr: Sei - IG - ShastR - ScottR (c11520500_11516530_t1)	1962-2012	2201			86	S	1	Y1
95	Klamath R Accr: Boyle - Keno (c11510700_11509500)	1960-2012	419			79	G	2	Y1
96	Klamath R Accr: Orl - Keno - SalmR (c11523000_11509500_t1)	1931-2012	11472			93	S	1	Y1[a]
97	Williamson R Blw Sprague R (11502500)	1918-1922, 1924-2012	7820	1578	2751	63	G	1	Y1
98	Williamson R Klamath Agency (11493500)	1955-1995, 1999-2012	3475	1563	2751	72	S	1	Y1
99	Williamson R Sheep Cr (11491400)	1974-2001, 2003-2005, 2007-2012	499	0	0	60	G	1	Y2
100	Williamson R Accr: Bl Sprg - SprgR - K Mrsh (c11502500_11493500_t1)	1956-1994, 2000-2012	224			58	G	1	Y1
101	Sprague R Chiloquin (11501000)	1922-2012	4121	1600	2535	56	G	2	Y1
102	Sprague R Beatty (11497500)	1954-2012	1362	1642	2535	54	G	2	Y1
103	NF Sprague R Power Plant (11495800)	1994-2012	174	1985	2535	80	G	1	N
104	Sycan R Snake Cr (11499100)	1974-2011	1440	0	0	63	G	1	Y3
105	Sprague R Accr: Chiloquin - Beatty (c11501000_11497500)	1955-2012	2759			57	G	1	Y1
106	Sprague R: Williamson R - Sprague (c11502500_11501000)	1924-2012	3699			71	G	1	Y1
107	Annie Spring (11503000)	1978-2004, 2011-2012	2	0	0	165	G	1	N
109	Salmon R (11522500)	1912-1915, 1928-2012	1943	1298	2664	148	S	1	Y1
110	Scott R Ft Jones (11519500)	1942-2012	1714	1319	2587	77	S	1	Y1
111	Shasta R Yreka (11517500)	1934-1941, 1946-2012	2047	1227	4303	66	G	3	Y1
112	Shasta R Montague (11517000)	1912-1913, 1917-1921, 1924-1933, 2002-2012	1726	1281	4303	69	G	3	N
113	Little Shasta R Montague (11516900)	1958-1978	121	1754	2506	65	S	1	N
114	Shasta R Accr: Yreka - Montague (c11517500_11517000)	2003-2012	321			48	G	1	N
115	Trinity R Hoopa (11530000)	1912-1913, 1917-1918, 1932-2012	7391	1149	2749	144	R/S	4	Y1
116	Trinity R Burnt Ranch (11527000)	1932-1940, 1957-2012	3727	1250	2749	135	S	4	Y1
117	Trinity R Accr: Hoopa - Burnt Ranch - SF (c11530000_11527000_t1)	1967-2012	1684			164	R/S	1	Y1
118	Trinity R Limekiln Glch (11525655)	1982-1991, 2003-2012	2100	1365	2749	146	S	4	N
119	Trinity R Lewiston (11525500)	1912-2012	1862	1417	2749	150	S	4	Y1
120	Trinity R Coffee Cr (11523200)	1958-2012	383	1630	2749	130	S	1	Y1
121	NF Trinity R Helena (11526500)	1912-1913, 1958-1980	392	1335	2691	127	S	1	N
122	Grass Valley Cr Fawn Lodge (11525600)	1977-2005	80	1047	1752	128	R	2	N
123	Trinity R Accr: Burnt Ranch - Lewiston (c11527000_11525500)	1933-1939, 1958-2012	1865			121	S	1	Y1
124	Trinity R Accr: Hoopa - Lewiston (c11530000_11525500)	1933-2012	5529			142	R/S	1	Y1
125	SF Trinity Hyampom (11528700)	1966-2012	1980	1122	2385	144	R/S	1	Y1

[a] These sites are calculated accretions that substantially overlap with other calculated accretions in Y1 category. Thus, for the sake of brevity, the results are presented only in the appendices rather than in the main report results. Despite the spatial overlap, trend evaluation is valuable because some of these sites have extremely long periods of record.

Table 5. List of estimated accretions between stream gages. The naming convention is downstream gage minus upstream gage minus tributary 1 minus tributary 2 (for example: "Klamath R accretions: Seiad - Iron Gate - Shasta R - Scott R" is accretions top the Klamath River between Iron Gate Dam gage (11516530) and Seiad Valley gage (11520500), excluding the Shasta River gage (11517500) and Scott River gage (11519500).

			Gage Numbers Used in Calculation			
River Basin	**Gage ID Code**	**Name**	**Downstream**	**Upstream**	**Tributary 1**	**Tributary 2**
Eel R	11472150_11471500	Eel R accretions: Dos Rios - Van Arsdale	11472150	11471500		
Eel R	11475000_11471500_t1	Eel R accretions: Fort Seward - Van Arsdale - MF Eel	11475000	11471500	11473900	
Eel R	11475000_11472150_t1	Eel R accretions: Fort Seward - Dos Rios - MF Eel - Outlet Cr	11475000	11472150	11472200	11473900
Eel R	11476500_11475800	SF Eel R accretions: Miranda - Leggett	11476500	11475800		
Eel R	11477000_11471500	Eel R accretions: Scotia - Van Arsdale	11477000	11471500		
Eel R	11477000_11471500_t1	Eel R accretions: Scotia - Van Arsdale - SF Miranda	11477000	11471500	11476500	
Eel R	11477000_11475000_t1	Eel R accretions: Scotia - Fort Seward - SF Miranda	11477000	11475000	11476500	
Klamath R	11502500_11493500_t1	Williamson R accretions: Blw Sprague - Sprague - Klamath Marsh	11502500	11493500	11501000	
Klamath R	11502500_11501000	Sprague R: Williamson R - Sprague	11502500	11501000		
Klamath R	11501000_11497500	Sprague R accretions: Chiloquin - Beatty	11501000	11497500		
Klamath R	11510700_11509500	Klamath R accretions: Boyle - Keno	11510700	11509500		
Klamath R	11523000_11509500_t1	Klamath R accretions: Somes Bar - Keno	11523000	11509500	11522500	
Klamath R	11520500_11516530_t1	Klamath R accretions: Seiad - Iron Gate - Shasta R - Scott R	11520500	11516530	11517500	11519500
Klamath R	11523000_11520500_t2	Klamath R accretions: Orleans - Seiad - Salmon R	11523000	11520500	11522500	
Klamath R	11530500_11520500	Klamath R accretions: Klamath - Seiad	11530500	11520500		
Klamath R	11530500_11520500_t1	Klamath R accretions: Klamath - Seiad - Somes	11530500	11520500	11522500	
Klamath R	11530500_11520500_t2	Klamath R accretions: Klamath - Seiad - Salmon R - Trinity R	11530500	11520500	11522500	11530000
Klamath R	11530500_11523000_t1	Klamath R accretions: Klamath - Orleans - Trinity R	11530500	11523000	11530000	
Klamath R	11517500_11517000	Shasta R accretions: Yreka - Montague	11517500	11517000		
Trinity R	11530000_11525500	Trinity River accretions: Hoopa - Lewiston	11530000	11525500		
Trinity R	11527000_11525500	Trinity R accretions: Burnt Ranch - Lewiston	11527000	11525500		
Trinity R	11530000_11527000_t1	Trinity R accretions: Hoopa - Burnt Ranch - SF Trinity Hym	11530000	11527000	11528700	
Mad R	11481000_11480410	Mad R accretions: Arcata - Blw Ruth Res	11481000	11480410		
Mattole R	11469000_11468900	Mattole R accretions: Petrolia - Ettersburg	11469000	11468900		
Redwood Cr	11482500_11481500	Redwood Cr accretions: Orick - 299	11482500	11481500		
Rogue R	14366000_14362000	Applegate R accretions: Applegate - Copper	14366000	14362000		
Rogue R	14369500_14366000	Applegate R accretions: Wilderville - Applegate	14369500	14366000		
Rogue R	14377100_14372500_t1	Illinois R accretions: Kerby - EF Illinois Takilma	14377100	14372500	14375100	
Rogue R	14372300_14361500_t1	Rogue R accretions: Agness - Grants Pass	14372300	14361500	14366000	
Rogue R	14343000_14342500	NF L Butte Cr accretions: Nr Lake Creek - Falls	14343000	14342500		
Rogue R	14359000_14337600	Rogue R accretions: Central Point - McLeod	14359000	14337600		
Rogue R	14359000_14339000	Rogue R accretions: Central Point - Eagle Point	14359000	14339000		

2.3 PRECIPITATION

2.3.1 Data Sources and Summaries

Monthly GIS grids of precipitation were downloaded from the PRISM Climate Group[12], which combines measured data from individual weather stations with an algorithm (incorporating phenomenon such as rain shadows, coastal effects, and temperature inversions) to produce a spatially continuous 4-km resolution digital grid for each month from 1895 to present (Daly et al 2002, 2004). For each year and month, the average precipitation in the area contributing to each gage was calculated using automated GIS methods.

2.3.2 Calculation of Antecedent Precipitation Index (API) and Use to Model Streamflow

Antecedent Precipitation Index (API) is an index of how much precipitation occurred in a preceding duration of time, with the precipitation in the current period assigned full weight and each preceding period assigned a progressively lower weight. API is a proxy for soil moisture and is a useful predictor of streamflow (Klein 2012).

To assist in assessing long-term trends, API was used to develop a predictive model for streamflow. API is more typically calculated from daily data and used as a predictor for storm flow, but in this report API is calculated from monthly data and the primary emphasis is on predicting flows during the dry summer months.

At gages dominated by surface runoff (see section 2.2.4 above for discussion of watershed classification), API was calculated for each gage, year, and month, by combining the precipitation in the given month with precipitation in the preceding 11 months, using the following formula:

$$API_i = (P_i) + (P_{i-1})(k^1) + (P_{i-2})(k^2) + (P_{i-3})(k^3) + (P_{i-4})(k^4) + (P_{i-5})(k^5) + (P_{i-6})(k^6) + (P_{i-7})(k^7) + (P_{i-8})(k^8) + (P_{i-9})(k^9) + (P_{i-10})(k^{10}) + (P_{i-11})(k^{11})$$

Where:

API_i = Antecedent Precipitation Index for month i (units = centimeters)
P_i = Precipitation for month i (units = centimeters)
k = Recession coefficient (ranges from 0 to 1)

At groundwater dominated gages, the API formula is identical, except 35 preceding months of precipitation were used, to account for multi-year memory in those systems[13]. If the recession coefficient is very low (e.g., 0.1) then the preceding months receive almost no weight in the API calculation, whereas if the recession coefficient is very high (e.g., 0.9) then the preceding months provide a large contribution to API (Figure 6). The recession coefficient was calibrated separately for each gage and month, by iterating through all possible values (i.e., 0.01 to 1.00 in steps of 0.01) and then selecting the recession coefficient that would result in the highest Spearman's rank correlation coefficient (Spearman's rho) between monthly average streamflow and monthly API[14]. Optimal recession coefficients generally followed an intuitive pattern according to watershed classification (i.e.,

[12] http://www.prism.oregonstate.edu/

[13] Mayer and Naman (2011) found that 3-yr precipitation was an important explanatory variable for flow at groundwater-dominated sites in the Upper Klamath Basin.

[14] Spearman's rank correlation is a non-parametric alternative to correlation that does not rely on assumptions of normality and is less sensitive to outliers than standard Pearson correlation. Spearman's rho ranges from -1 to 1 according to whether variables are positively or negatively correlated (positive rho indicates positive correlation and a negative rho indicates negative correlation). The associated p-value provides a test of statistical significance.

recession coefficients were highest at groundwater-dominated sites, intermediate at surface-dominated snowmelt basins and surface-dominated rain-snow basins, and lowest at surface-dominated rain basins) (Appendix E). The relationship between streamflow and API was not always linear, so the model uses a LOESS smoother rather than a standard regression to predict flow.

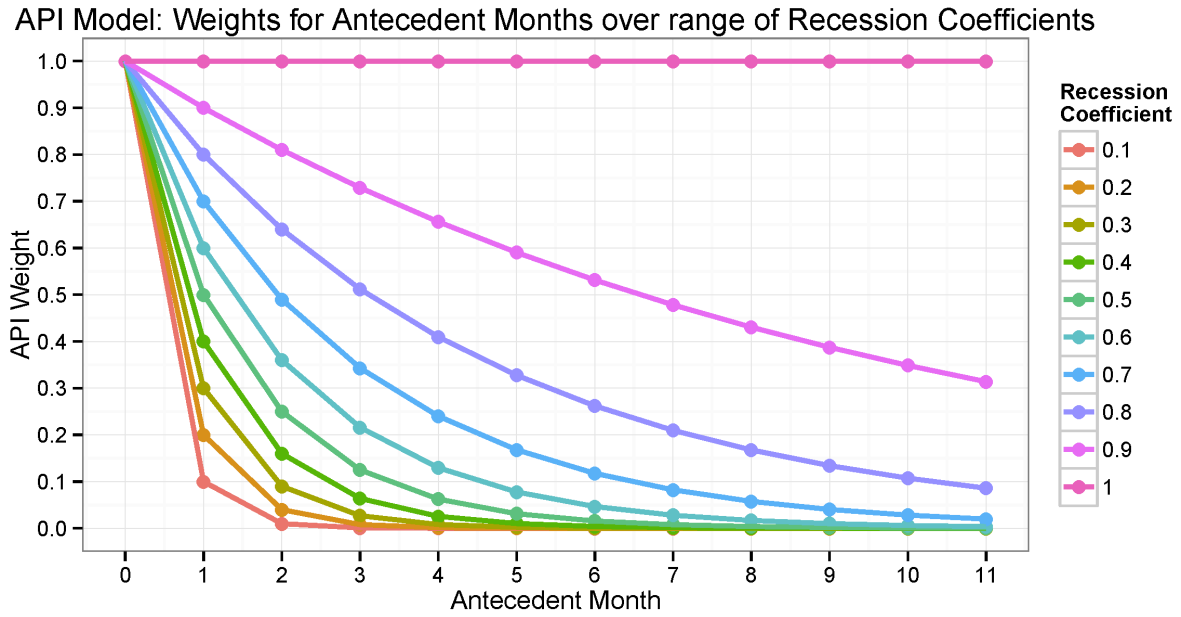

Figure 6. Illustration weight assigned to each of the preceding 11 months in the API calculation. Each line corresponds to a different recession coefficient.

2.4 ANNUAL WATER BUDGETS

Precipitation and streamflow data were combined to construct simple annual water budgets for the watershed areas contributing to each gage. Water is removed from the system by factors such as evapotranspiration by vegetation and withdrawals by humans. The difference between precipitation and streamflow is the sum of all these water removal factors. A key output of the water budget is the runoff coefficient, which is the percent of precipitation that becomes streamflow. Long-term trends in runoff coefficient were evaluated using methods described in section 2.5. If runoff coefficient shows a decreasing long-term trend, then withdrawals or evapotranspiration are increasing over time (assuming the trend is not due to measurement errors in streamflow or precipitation).

2.5 LONG-TERM TRENDS IN STREAMFLOW AND PRECIPITATION

Long-term trends in metrics of streamflow, precipitation, and water budgets were analyzed using the nonparametric Mann–Kendall test[15], which is recommended in the USGS *Statistical Methods in Water Resources* manual (Helsel and Hirsch 2002) and is commonly used for assessing hydrologic trends (Pavelsky and Smith 2006, Mayer and Naman 2011, Chang et al. 2012). A p-value of 0.10 was used as the threshold for statistical significance, following the convention used in similar previous analyses (Madej 2011, Chang et al. 2012). The Mann-Kendall test does not rely on assumptions of normality of residuals, constant variance and linearity (Helsel and Hirsch 2002). To increase comparability of trends between gages, trend tests were run on the 60-year period 1953–2012 with some gaps allowed. Following guidance from Helsel and Hirsch (2002), gages that did not have at least 20% coverage (4

[15] Using the WQ add-on package in R

years[16]) in each third (1953–1972, 1973–1992, 1993–2012) of the 60-year period were excluded[17]. Slope of the trend was calculated using the non-parametric Sen slope estimator method. An additional set of Mann-Kendall trend tests were also run for the entire period of record[18] for sites with at least 30 years of data (Table 4). These additional period of record trend tests are not presented in the main body of this report, but are included in the electronic Appendix H.

Precipitation is the source of streamflow and is therefore directly correlated with the amount of streamflow. Decreasing trends in streamflow may occur because of changes in precipitation, other climate factors aside from precipitation (e.g., air temperature, wind, humidity, coastal fog, etc.), vegetation, or by changes in withdrawals. To evaluate the long-term trends in the combined effects of these non-precipitation factors on streamflow, I assessed changes in the relationship between precipitation and streamflow changes over time (i.e., years and decades) using the flow versus API model, as described in the following paragraph.

The LOESS curve in the flow versus API model is a quantitative description of the overall (i.e., best fit) relationship between flow and precipitation across the entire period of record of streamflow; however, the observed values for any given year rarely lie exactly on the LOESS curve (Figure 7). The difference between the observed value (i.e., monthly average of daily measured streamflow for a particular month and year) and the expected value (i.e., the modeled streamflow for a particular month and year, based on the LOESS relationship between API and flow across the period of record [all years] for that particular month) is referred to as the "residual"[19]. The residual represents the variability in streamflow that is not explained by the variability in precipitation (i.e., it is the combined net effect of all non-precipitation factors affecting streamflow), including the accumulation of all measurement errors. In the example time series shown in Figure 8, residuals were mostly positive during the first half of the period of record but mostly negative during the second half of the period of record, indicating a long-term shift in the relationship between streamflow and precipitation. Following the recommendations of Helsel and Hirsch (2002), I ran Mann-Kendall tests on the time series of the residual to statistically evaluate long-term trends in streamflow accounting for the variability caused by precipitation[20]. Comparing the Sen slope of the flow trend and the Sen slope of residuals trend allows quantification of the relative contribution of precipitation to the observed trend in flow.

[16] One exception was the Chetco River (gage 14400000), which had only 3 years of data for the first third (1953–1972), but was still used for the 1953-2012 period.

[17] Number of complete hydrologic years per site include in the 1953–2012 trend tests ranged from 34 to 60. The 'Trend' column of Table 4 lists which gages were used for 1953–2012 trend analysis.

[18] The term period of record means all years with available data; however, if a site had just a few years early in the record and then a long gap, the early years were excluded from the trend test.

[19] The residual is calculated as observed minus expected. Thus, a negative residual means the model over-estimated, while a positive residual means the model under-estimated

[20] Due to time constraints, I ran these trends tests for all gage-months, even in cases where there was not a significant relationship between API and flow. The results of the trend tests in such cases are not meaningful (i.e., do not represent the trend in flow with the effect of precipitation accounted for). In these cases, it would have been safer not to run the trend tests, or to run them on flow rather than the residual. However, the lack of a significant relationship between API and flow is relatively rare (especially at unregulated sites) and where/when it does occur, the LOESS line is generally close to horizontal which means that the results of the trend test in the time series of the residuals should be nearly identical to the results of the trend test in the time series of flow. Thus, as a practical matter, the number of site months with erroneous results is likely quite low.

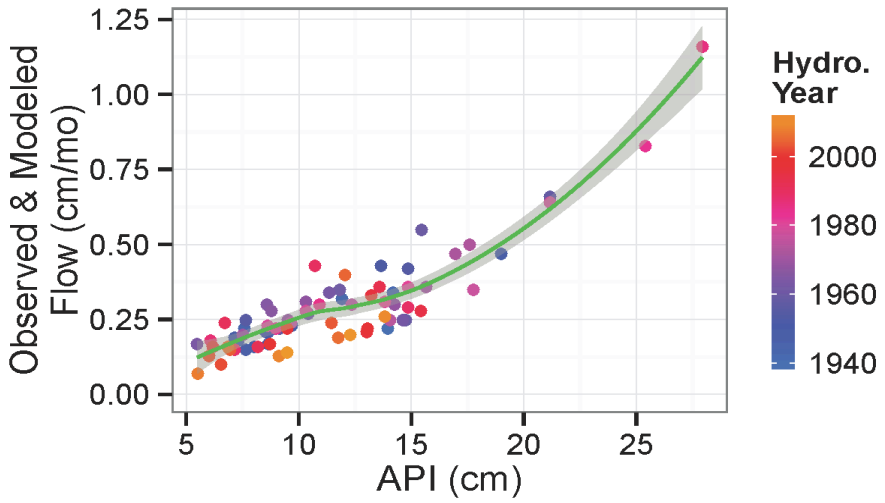

Figure 7. Relationship between the streamflow and API at an example gage (South Fork Eel River at Miranda gage #11476500) for the month of August. Points are observed data (one for each year) and the green line is the LOESS best-fit curve.

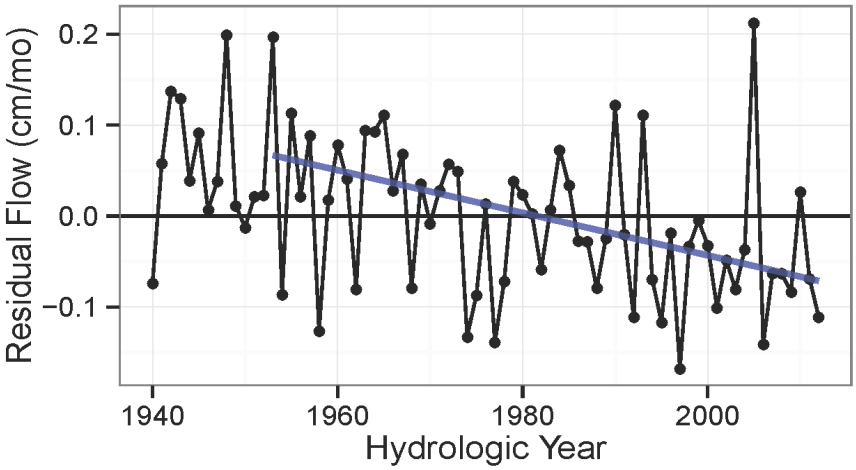

Figure 8. Time series of the residual from the streamflow versus API model at an example gage (South Fork Eel River at Miranda gage #11476500) for the month of August. Points are observed data (one for each year) and the blue line is the long-term trend for 1953-2012.

Precipitation, and hence streamflow, within the study area are strongly influenced by the Pacific Decadal Oscillation (PDO) and El Niño/Southern Oscillation (ENSO; Mantua and Hare 2002). The PDO has a multi-decadal periodicity, while the ENSO varies on much shorter time scales of 6-18 months (Mantua and Hare 2002). An analysis of 109 years of winter precipitation for six combinations of ENSO and PDO conditions (warm or cool PDO paired with warm [El Niño], neutral, or cool [La Niña] ENSO) found that long-term average precipitation in the SONCC ESU area was higher in cool PDO phases than in warm PDO phases, except in years with neutral ENSO (Miller and Goodrich 2007). Cool PDO regimes dominated in 1947-1976, switching to warm from 1977 through the late 1990s (Mantua and Hare 2002). From 1999 to the present, cool regimes have again prevailed (Figure 9; Andrews and Antweiler 2012). Thus, the 1953–2012 period used in this study for the time series trend tests began in the middle of cool phase, included a warm phase, and

ended again in the middle of a cool phase. One advantage of the streamflow versus API model is that it allows the variability in precipitation to be accounted for in the evaluation of monthly streamflow trends; however, the results of time series trends for other parameters (e.g., 7-day, 30-day, and 90-day minimum streamflow; annual streamflow; monthly and annual precipitation; and runoff coefficient) should be interpreted within the context of the PDO cycles.

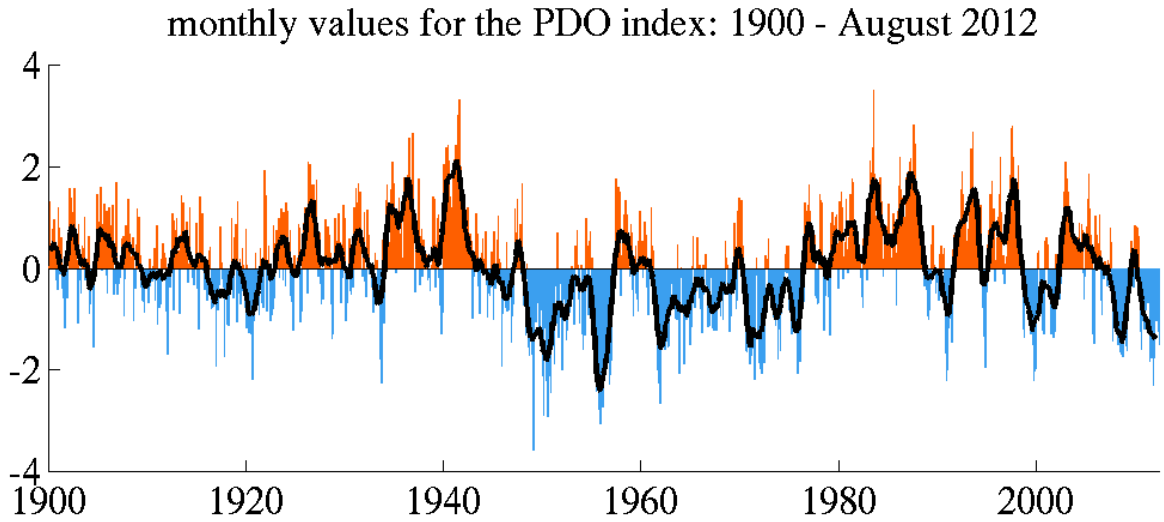

Figure 9. Sea surface temperature-based monthly Pacific Decadal Oscillation (PDO) index from 1900–2012. Graphic from: http://jisao.washington.edu/pdo/graphics.html

2.6 WATER CONSUMPTION FOR HUMAN USES

2.6.1 Residential Indoor/Outdoor and Commercial Water Use

Summary: Residential indoor/outdoor and commercial water consumption was estimated by multiplying human population by estimated rates of per capita water use.

Details: Indoor water use is relatively constant throughout the state of California, but outdoor water use is much higher in inland regions than in coastal regions due to higher landscape irrigation demands in the hotter inland climate (State of California 2010). In urban water districts in California's North Coast hydrologic region, average per capita use (i.e., total water volume delivered divided by population) is 165 gpd/person (i.e., 115 gpd for residential [68 for indoor use and 47 for outdoor use], 18 gpd for commercial, 8 gpd for industrial, and 24 gpd for un-reported; State of California 2010). Urban Water Management Plans (UWMP) submitted to the State of California by local water districts[21] indicate the 10-year average per-capita water use within the North Coast region ranged from a low of 97 gpd/person in coastal Crescent City to a high of 321 gpd/person in inland Yreka. For both California and Oregon, I use the regional average of 68 gpd to estimate for indoor water use, estimate outdoor water use separately (described in following paragraph), and ignore commercial/industrial water use assuming that the relatively high estimate of outdoor water use compensates for lack of explicit inclusion of commercial/industrial.

[21] Urban water suppliers in California that provide over 3,000 acre-feet of water annually or serve more than 3,000 customers are required to prepare an UWMP and submit it to the state. Coastal jurisdictions with UWMP are: Crescent City, McKinleyville, Arcata, Eureka, Humboldt Community Services District, Fortuna, and the Humboldt Bay Municipal Water District. Yreka is the only water district in the inland portion of the study areas that has an urban water management plan.

In addition to climate, another factor influencing per-capital water use is per-capita landscaped area. Relative to urban areas, per-capita landscaped area in rural areas is presumably substantially larger because larger parcels provide space for gardens, greenhouses, orchards, and livestock, although available data regarding water use in rural residential areas are limited. Sanctuary Forest (2008) estimated household water use in the Mattole headwaters at 900 gpd during the summer months, including 475 gpd for gardens and lawns and 200 gpd for leaks and overflow. Dividing the 675 gpd by an assumed 3 persons per household results in 225 gpd of outdoor use/person, which is the value I used in this analysis for outdoor water consumption. Outdoor water use of 225 gpd/person is similar in magnitude to estimates of water used by marijuana plants in the watersheds of Salmon Creek and Redwood Creek (tributaries to the South Fork Eel River) recently conducted by the California Department of Fish and Wildlife (CDFW 2013)[22].

Using block-level data from the 2010 U.S. Census and the Protected Areas Database of the U.S. from the Conservation Biology Institute, the SILVIS Lab at the University of Wisconsin-Madison created a national GIS dataset of human population density by re-apportioning the population on publicly owned lands to private lands within the same census block to improve geographic accuracy (Radeloff et al. 2005)[23]. I used this GIS dataset to estimate the human population for each coho salmon population and gaged watershed within the study area. The resulting human population was then multiplied by the per-capita estimates of indoor and outdoor water use to obtain water use estimates for each gaged watershed and coho salmon population. I was unable to assess the accuracy of the census data, but assume that the data likely underestimate population in the most rural and remote portions of the study area based on national analyses (O'Hare 2010).

2.6.2 Agricultural Water Use

Summary: Annual agricultural water use estimates from the California Department of Water Resources (CDWR) and the Oregon Water Resources Division (OWRD) were spatially apportioned using agricultural pixels from the 2006 National Land Cover Database and divided evenly into a 6-month irrigation season to estimate monthly agricultural water use.

Details: CDWR uses crop land use surveys and water use models[24] to estimate agricultural water use for California Water Plan Updates (Bulletin -160). The models operate at several spatial scales, with the smallest being the Detailed Analytic Unit (DAU) which is approximately sub-basin to basin scale. The models combine pan evaporation (calculated from meteorological data) and crop coefficients to estimate crop evapotranspiration. Crop evapotranspiration is then compared to soil characteristics, crop rooting depth, and meteorological data to estimate the annual evapotranspiration of applied water (ETAW). ETAW is an estimate of the net (i.e., adjusted for seepage to groundwater) irrigation water needed to produce a crop. Land use surveys provide the acreages of 20 different categories of crops within a DAU.

[22] CDFW used aerial photos to map the number of residences, square footage of greenhouses, and outdoor marijuana plants (CDFW 2013). The gardens and greenhouse were often proximal to residences and dividing the total estimated marijuana water consumption (231,812 gpd) by the total number of residences (491) results in 472 gpd, which can then be divided by three persons per residence to yield 156 gpd/person (excluding other outdoor water use besides marijuana).

[23] http://silvis.forest.wisc.edu//maps/wui/2010/download

[24] Consumptive Use Program PLUS, the original Consumptive Use Program (CUP) and the Simulation of Evapotranspiration of Applied Water (SIMETAW). http://www.water.ca.gov/landwateruse/models.cfm

I obtained spreadsheets with DAU-level crop acreages and crop ETAW for each year 1998 to 2001 from the DWR website[25] and 2002-2005 data from DWR by request[26]. For each DAU, I multiplied the area of each crop by the ETAW (in units of acre-ft. of water per acre of crop) of each crop to obtain the volume of ETAW for each crop and then summed the volumes together to obtain the total ETAW. To aggregate or parse the results to other spatial scales (i.e., gaged watershed and coho salmon populations), I spatially apportioned the ETAW using agricultural pixels identified from the 2006 National Land Cover Database (Fry et al. 2011). Annual ETAW volume was then temporally apportioned by using the simplistic assumption that irrigation was applied evenly across an entire six-month irrigation season (April 1 – October 1)[27], which is justified for the basic comparative purposes that these data are used for in this analysis.

To estimate agricultural ETAW for Oregon, I used a similar process as for California but used county-level agricultural water demand estimates from HDR Inc. (2008) rather than DAU-level ETAW data from CDWR. In the 2014 version of this report, I directly compared the Oregon and California data; however, I later realized that the HDR Inc. demand estimates included embedded adjustments for conveyance efficiency (constant 80%) and irrigation efficiency (varied by county/crop, range 50-90%), so are higher than ETAW. Therefore, for the 2015 revision of this report, I multiplied the Oregon water demand values by an adjustment factor of 0.56[28] to back-calculate ETAW values that can be directly compared to the California ETAW data.

2.6.3 Other Water Uses Not Included

Estimates of water consumption for industrial, thermoelectric power (i.e., cooling for electronic power generation), livestock, aquaculture, and mining water uses are not included in this analysis. County-level estimates for 2005 for these uses are available from the USGS (Kenny et al. 2009). However, there is no straightforward way to spatially downscale these estimates to sub-basin or watershed scales. Within the study area, livestock is the most geographically widespread of these water uses, although the other water uses could be significant in specific areas. Daily water consumption per animal is approximately 35 gallons for dairy cows and 12 gallons for beef cattle (Lovelace 2009).

2.7 COMPARISON OF HUMAN WATER USES AND STREAMFLOW

The estimates of residential/commercial and agriculture water use in the watershed contributing to each stream gage were converted to instantaneous rates (i.e., cfs) and compared to summary metrics of streamflow (i.e., minimum 7-day average flow, minimum 30-day average flow, and monthly average flows) computed for that gage's streamflow data. These comparisons serve several purposes. First, they provide an estimate of the potential magnitude of human alteration to the streamflow at each gage. Second, they can be used to help infer the cause of long-term trends in streamflow. For example, if human water use is equivalent to only 1% of September streamflow, but September streamflow exhibits a long-term declining trend, then factors other than human water use are likely responsible for the decline.

[25] http://www.water.ca.gov/landwateruse/anlwuest.cfm. 1999 data were not used because spreadsheet format was different

[26] Gholam Shakouri, contact information at http://www.water.ca.gov/landwateruse/contacts/

[27] In reality, the length of the irrigation season would vary by crop and location and water use would not be distributed evenly across the entire irrigation season. This assumption likely over-estimates irrigation in the spring (and perhaps late summer and early fall) and under-estimates irrigation during mid- summer.

[28] 0.56 adjustment factor was derived by multiplying the 80% conveyance factor (same value used by HDR Inc.) and 70% irrigation efficiency factor (the middle of the range of values presented by HDR Inc.).

2.7.1 Limitations of Comparisons Between Water Use and Streamflow

Due to data gaps, simplifications, and assumptions, the comparisons of water use and streamflow are relatively rough and preliminary. In most cases, these comparisons cannot be reliably used to estimate an unimpaired (i.e., with no diversions, groundwater pumping, or reservoir storage) hydrograph. Issues include:

1. Streamflow and human water use are compared at the scale of entire gaged watersheds, most of which are relative large in size. As noted in section 1.3 above, smaller streams are much more vulnerable to being temporarily dried up due to water withdrawals than larger streams. Thus, even if human water use is only a relatively small percentage of summer streamflow within a larger watershed, many small streams within that larger watershed could be periodically dried up due to the instantaneous effects of multiple high-capacity pumps operating simultaneously. A single drying incident needs only to last a few minutes to kill all coho salmon juveniles within the temporarily dry reach. Thus, the capacity of a watershed to successfully support summer rearing of coho salmon juveniles can be substantial reduced even if human water use is a small percent of streamflow.

2. The water use estimates are based on the distribution of agricultural land and human population within gaged watershed boundaries, and therefore do not include specific diversions to areas outside watershed boundaries (i.e., adjacent municipal use on the Smith, Chetco, and Mad rivers) or major out-of-basin transfers (i.e., Eel River and Trinity River). All calculations are done at a watershed scale and do not explicitly include any storage or diversion infrastructure.

3. The water use estimates do not distinguish between the diversion of surface water, which would directly result in decreased streamflow, and groundwater pumping, which depending on site-specific conditions may or may not be connected to surface water. In addition, there could be substantial temporal lags between groundwater pumping and effects on streamflow (i.e., in some cases, it may be possible that water pumped in September would not have become streamflow until October, and so if early precipitation occurs then the September pumping could have little effect on low flows).

4. The water use estimates do not consider storage. In areas where irrigation water is augmented by reservoirs, estimating an unimpaired flow would not be appropriate by simply summing current irrigation and current streamflow.

Despite these limitations, the comparisons do provide an informative and useful preliminary examination of how human water use could affect streamflow across the study area. In some coho salmon populations within the ESU, much more detailed analyses of water use and unimpaired flow have already been conducted, or are in the process of being conducted, as part of other projects.

2.8 RESERVOIR STORAGE AND FISH PASSAGE AT DAMS

2.8.1 Reservoir Storage

Dams and reservoirs can cause major alterations to the hydrology of a watershed and channel forming and maintenance processes, although such alterations are difficult to quantify. Detailed analyses of reservoir inflows and outflows are beyond the scope of this project and not possible in all watersheds due to data gaps. Therefore, a simpler metric was used to assess effects of dams and reservoirs. The sum of the water storage volume of all reservoirs in the watershed contributing to a gage was calculated as a percent of total annual precipitation in that watershed using the NOAA Fisheries Dams 2005 GIS layer (Goslin 2005) for California, the Oregon Dams 2010 GIS layer from the

Oregon Department of Water Resources[29], and the 1981-2010 "normals" from the PRISM precipitation dataset (see section 2.3.1 above). While this metrics does not take into account how the dams are operated (e.g., what time of year water is being stored/released and the final destination of impounded water) nor how far downstream the gage is from the reservoir, it provides a useful approximation of the potential for hydrologic alteration due to dams/reservoirs. The higher the ratio of reservoir storage to total annual precipitation, the higher the potential for hydrologic alteration. The metric was also used in watershed classification (see section 2.2.4 above).

2.8.2 Dams as Fish Passage Barriers

In addition to hydrologic effects, dams can also be barriers to coho salmon migration. Modeling conducted to characterize the population structure of the SONCC coho salmon ESU (Williams et al. 2006) provided GIS files for each population that quantify the number of kilometers of habitat with Intrinsic Potential to support coho salmon rearing (IP-km). The Williams et al. (2006) modeling also included an initial delineation of natural and anthropogenic barriers and the amount of IP-km upstream from those barriers. Using these data, Douglas Chow of the NOAA Fisheries North Coast Office calculated population-level summaries of the percentage of IP-km blocked by anthropogenic barriers and provided his calculations to me. In the years since the initial IP modeling, some dams have been removed and additional information on passage barriers (both natural and anthropogenic) is now available. Using updated GIS datasets of fish barriers and fish distribution from the states of California[30] and Oregon[31], I updated the calculations of the percentage of IP-km blocked by dams in each coho salmon population. Only dams that are complete upstream migration barriers to all life stages of coho salmon were utilized in the analysis.

2.9 OTHER WATERSHED INDICATORS OF HYDROLOGIC ALTERATION

2.9.1 Impervious Area

When a watershed becomes urbanized, the increased amount of impervious surfaces alters hydrologic patterns to the detriment of coho salmon. Infiltration is reduced and surface runoff increases. Discussion on this subject was summarized in chapter 3 of the draft recovery plan for SONCC coho salmon, so is not repeated here. As part of the recovery plan's threats assessment in 2007, Kier Associates used the impervious surfaces layer from the 2001 National Land Cover Database 2001 (Homer et al. 2007) to calculate the percent of each coho salmon population covered in impervious surfaces (Kier Associates and NMFS 2008). I use those results in this report as an indicator of hydrologic alteration.

2.9.2 Road Density

By compacting soil and short-circuiting shallow subsurface flow paths, roads affect the timing and magnitude of peak flows (Grant et al. 2008). The magnitude of alteration is dependent on both the total amount of roads as well as their location in the watershed. As part of the recovery plan's threats assessment in 2007, Kier Associates calculated road densities for each coho salmon population using three different sources of GIS roads data from: 1) from CalFIRE for coastal California, 2) Legacy—

[29] Downloaded from: http://spatialdata.oregonexplorer.info/geoportal/catalog/download/download.page. Gold Ray Dam and Savage Rapids Dam on the Rogue River have been removed since the dataset was last updated, so I excluded them from my analysis.

[30] California Fish Passage Assessment Database, 2/8/2013 version (http://www.calfish.org/DataandMaps/CalFishDataDownloads/tabid/93/Default.aspx)

[31] Oregon Fish Habitat Distribution - Current and Historical Coho, 6/27/2013 version (http://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=fishdistdata) and Oregon Fish Passage Barriers , 6/22/2012 version (https://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=fishbarrierdata)

The Landscape Connection for inland California, and 3) the U.S. Bureau of Land Management and Conservation Biology Institute for Oregon (Kier Associates and NMFS 2008). I use those results in this report as an indicator of hydrologic alteration.

2.10 DETERMINING POPULATION-LEVEL STRESS AND THREAT RANKS

As noted above, some indicators were calculated at the geographic scale of an entire coho salmon population while others were calculated for the watershed area contributing to a stream gage. These two geographic scales are rarely identical and NMFS requires stress and threat ranks to be determined at the geographic scale of an entire coho salmon population. Thus, I used professional judgment to combine the results of the two geographic scales of indicators with the best available information on stream hydrology to determine, for each coho salmon population and life stage, a stress rank (i.e., very high, high, medium, or low) for altered hydrologic function and a threat rank for dams and diversions.

Developing these population-level stress and threat ranks was difficult, given the uneven availability of streamflow data within and between populations. Judgments were required because it would not be meaningful to use a simple mathematical formula (i.e., averaging the results from all gages within a population) to derive population-level summaries, due to the following reasons:

i. the number of gages within a population (some populations had no gage, some had a single gage, and some had multiple gages);

ii. the location of gages within a population and whether they are representative of population-wide conditions, areas of high intrinsic potential, or neither (i.e., a gage located on a single small tributary with low intrinsic potential may not be relevant for assessing hydrologic alteration in important coho salmon habitats);

iii. the number of years of data affects which indicators can be calculated for that gage (minimum of 34 years of data required for statistical validity in assessing long-term trends, but only one year of data required to calculate human water use as a percent of minimum 30-day streamflow);

iv. the length of the gaged period of record relative to the history of human alteration (in some cases such as the Shasta River example discussed in the Executive Summary, significant water withdrawals had already been occurring for many decades prior to the start of streamflow measurements).

My professional judgments also considered the 2012 public draft of NMFS' coho recovery plan for SONCC coho salmon as well as the findings of the ODFW (2008) expert panel. Information from the 2012 public draft recovery plan that was considered included the population profiles (i.e., a chapter for each coho salmon population summarizing available information including maps, land use history, land ownership, current distribution of coho salmon, and a rank and short written description for each stress and threat, including altered hydrologic function and dams and diversions) and the relevant portions of Chapter 3 (Stresses and Threats). ODFW (2008) only presents the rankings for the paired interactions between threats and limiting factors (stresses), not the ranking for each limiting factor (stress) and threat in isolation because those were considered to be solely an interim preliminary step in the process of deriving final rankings. ODFW (2008) summarized their findings on a 3-category scale (primary concern, secondary concerns, and not primary/secondary concern), which I translated to a four-category scale by assuming that limiting factors/threats not listed as primary or secondary concerns were a low stress/threat.

There was no strict system for how much weight was given to each indictor when deriving the stress and threat ranks; however, the following remarks provide some information on the approach used. The ranks presented in the 2012 public draft of the recovery plan were used as the starting point, but were changed when contradicted by the indicators, contradicted by discussion in the 2012 public draft population profiles, or where populations sharing similar conditions (i.e., land use, geography, and climate) had been given different ranks. It was my intent to use a consistent approach across all populations, such that the differences in ranks between populations could be justified and explained. Where available (i.e., populations with stream gages), "Human water use (domestic plus agricultural) as a % of 30-day minimum flow" was afforded much more weight than "Human population density" and "% of watershed area in agriculture", because the water use indicator is a more direct and sophisticated measure of hydrologic alteration that integrates the data from the other two indicators (which were given relatively low weight) into a single metric. Substantial weight was also placed on the "Reservoir storage as a % of precipitation", "Statistically significant trend in minimum 30-day average flow", and "Statistically significant trend in average September flow with the effect of precipitation accounted for", with the latter two indicators interpreted within the context of the history of hydrologic alteration (i.e., as discussed above, water withdrawals often began long before stream gaging started). The indicator "Road density" was given moderate weight. At the population level, the indicator "% impervious surfaces" had only limited utility because all but two of the populations rated as Very Good.

The geographic resolution of the analysis is limited by the number and location of stream gages. Even if a particular gage shows little or no long-term trend, there could be substantial reductions in the flow in upstream tributaries that are very localized (i.e., desiccation of one or more small streams by water withdrawals). This could affect coho salmon in a population by removing available habitat even though the flow-related habitat reduction may not be detectable in gage-level analyses. This is particularly important because coho salmon habitat is not evenly distributed throughout an entire population area; instead, the habitats with the highest intrinsic potential are disproportionately located in a relatively limited number of low-gradient valleys which are also the same locations most likely to have human development, agricultural activities, and water diversions. My professional judgments attempted to take this into account by placing emphasis on the highest IP habitats (Williams et al. 2006) and reviewing detailed GIS maps of agricultural land use, developed areas, and human population density from the U.S. census, rather than solely relying the gage-level or population-level data summaries.

3 RESULTS AND DISCUSSION

3.1 LONG-TERM TRENDS IN STREAMFLOW AND PRECIPITATION

Summaries of the 1953–2012 Mann-Kendall trend tests for precipitation and flow are shown in Table 6 through Table 9[32]. While very few gaged watersheds showed significant decreases in annual precipitation, seasonal changes were evident (Table 6). The most geographically widespread trend was decreased September precipitation, which occurred at more than two-thirds of gaged watersheds (Table 6). Decreased September precipitation is particularly meaningful for coho salmon juveniles because it may indicate a lengthening of the dry summer season during which streamflows are low across much of the study area. Other precipitation trends were more geographically limited and included: decreased August precipitation primarily in the Eel and Trinity Basins in southeastern portion of the study area, increased April precipitation in many parts of the Middle/Upper Rogue

[32] Another set of Trend tests was also conducted for the entire period of record at each gage but are not presented in the report text. They are included as Electronic Appendix H.

Basins and the Upper Klamath Basin, increased May through July precipitation in parts of the Eel River Basin (the absolute amount of precipitation in these months is still very low relative to the rest of the year), and decreased January precipitation in the Middle Klamath Basin as well as parts of the Eel Basin and the upper Illinois (Table 6). September was the only month with a geographically widespread decreasing trend in API, and it appears to be caused by a decreasing trend in September precipitation (not prior months)(Appendix A).

Overall, the percent of gage-months with significant flow decreases substantially outnumbered those with significant increases, but flow regulation appeared to exert a strong influence (Table 7). At un-regulated (i.e., total reservoir storage less than 0.5% of annual precipitation) and regulated sites, declining flow trends vastly outnumbered increasing flow trends for November through April. For the remainder of year (May through October), regulated and unregulated sites showed opposing patterns with increasing trends outnumbering decreasing trends at regulated sites and decreasing trends outnumbering increasing trends at unregulated sites. In some rivers (Rogue, Applegate, and Trinity) increased May through October flows are due to dam construction partway through the 1953–2012 trend period, while in others (Eel River) water releases from existing dams were increased to benefit fisheries. At regulated gages, the month with the largest percentage of declining flows was February (67%). September flows (Figure 10) declined at 66% of the unregulated gages, more than in any other month (Table 7), likely due in part to decreased precipitation in that month (Table 6). Declining fall flows could affect migration and spawning of adult coho salmon, which use flow increases as migratory cues and a means by which to enter small streams. The percent of sites with flow declines in the months of September through December varied by month with a range of 14-66% at unregulated sites and 28-34% at regulated sites.

Annual flows declined at approximately 20% of gages (geographically concentrated in the Upper Klamath Basin), with only two gages (Trinity River at Lewiston[33] and calculated accretions to the Klamath River between Keno and Boyle) showing significant increases (Table 7). Runoff coefficients (annual runoff as a percent of annual precipitation) are significantly declining at approximately 40% of the gages within the entire study area and only the four gages, including the two mentioned in the previous sentence, showed significant increases (Table 8). The cause of the decreasing trends in runoff coefficient is unclear. Potential explanations include some combination of increased vegetation/forest evapotranspiration (from climate change and/or change in forest stand structure/composition) and/or increased diversions. Years with lower precipitation tend to have lower runoff coefficients (Fischer et al. 1996)[34], and thus decreased precipitation could also be contributing to declining runoff coefficient[35].

Hydrologic regulation had a large effect on trends in the minimum 7-day, 30-day and 90-day average flows. Approximately 43-48% of unregulated sites showed declines while only 2-4% increased (Table 8). In contrast, 41-44% of regulated sites increased while 14-22% decreased. Trends in baseflow

[33] Inter-basin water exports are not accounted for (i.e., are not included as surface runoff because they are diverted upstream of the gage) in the calculation of the runoff coefficient, so it is likely that decreased water exports from the Trinity River to the Sacramento Basin are responsible for the increased runoff coefficient.

[34] I conducted exploratory analyses within the study area and confirmed this relationship, but do not present the results in this report.

[35] Very few sites showed statistically significant declines in annual precipitation (Table 6) but the inherently large inter-annual variations in annual precipitation make it difficult to statistically establish such trends. It would be possible to use a regression (or LOESS smoother) between runoff coefficient and annual precipitation to remove the effect of precipitation from the runoff coefficient trend, similar to how API was used in this report to remove the effect of precipitation from monthly flow trends. Due to time and budget constraints, this was not done.

index (minimum 7-day average flow as a percent of annual flow) were similar to those of minimum 7-day average flows, except that the percentage of regulated sites with increases was higher (Table 8). A map of trends in minimum 30-day average streamflow is provided in Figure 11.

Trends in the timing of the minimum 7-day, 30-day and 90-day average flows, were largely confined to regulated sites (Table 8), with those flows occurring later in the calendar year[36] at 45-47% of regulated sites but only 4-11% of unregulated sites. The streamflow centroid (the date by which 50 percent of the runoff in a hydrologic year has occurred) occurred significantly later at 39% of unregulated sites and 62% of regulated sites, with few sites decreasing. This shift towards later runoff is the opposite of patterns detected in previous analyses (Regonda et al. 2005, Hidalgo et al. 2009) that indicated earlier runoff in the western United States in response to climate change causing earlier snowmelt and precipitation form shifting from snow to rain. Potential explanation for this pattern, which merits further investigation, is the presence in this study of many rain-dominated streams, streams heavily impacted by human diversions and flow regulation, and shifting timing of precipitation. Chang et al. (2012) found very few significant trends in the streamflow centroid in unregulated streams in Oregon, Washington, Idaho, and western Montana for the years 1958 to 2008.

To illustrate results for one example site and month (Mattole River at Petrolia gage 1146900 for the month of September), Figure 12 presents the Mann-Kendall time series trends for flow, flow residual (i.e., flow with the effect of precipitation accounted for), and API. The results from this surface-runoff rain-dominated system indicate declining trends in September for both streamflow (1.28% per year, $P < 0.001$) and API (0.7% per year, $P = 0.05$). There is a strong positive correlation between API and flow (spearman's rho = 0.82), indicating that the API model should be able to explain a large percent of the inter-annual variability in September flow. The declining time series trend in model residual indicates that streamflow is declining (0.612% per year, $P < 0.001$) even when the effect of precipitation is accounted for. Comparison of the trend slopes for flow and precipitation indicate that 48% (0.612/1.28) of the observed decrease in September flow is attributable to precipitation while the remainder is due to other factors. Figure 13 is a similar plot for Scott River near Fort Jones gage 11519500 for September, showing a significant declining trend in flow despite the lack of significant trend in precipitation. Similar plots for all other sites and months are available in Appendix B, with summaries available in Table 9.

Trends in flow with the effect of precipitation accounted for varied by month and degree of hydrologic function (Table 9). Summer base flows declined significantly in many streams, even when the effect of precipitation was accounted for. Decreasing trends substantially outnumbered increasing trends for most months except July through September at regulated sites and January and March at unregulated sites. The months with highest percentage of unregulated sites with declining trends were July through November (36 to 48%). There were a greater percentage of site-months with significant trends for flow with the effect of precipitation accounted for than for flow alone (i.e., without accounting for precipitation), likely because accounting for precipitation reduces inter-annual variation (Table 7, Table 9). A map of trends in September streamflow with the effect of precipitation accounted for is provided in Figure 11. The most pristine surface-runoff dominated watersheds within the ESU (i.e., those with very few diversions and relatively little landscape disturbance), such as Elder Creek, Smith River, Chetco River, Salmon River, and tributaries to the Klamath River between

[36] Because the lowest flows of the year often occur around October 1 (the transition from one hydrologic year to the next), the magnitude and timing of minimum 7-day, 30-day and 90-day average flows were calculated for calendar years rather than for hydrologic years. This avoids situations in which, for example, the 7-day minimum flow in one hydrologic year occurs on September 30 and the next hydrologic year it occurs October 1 (just one day later).

Seiad Valley and Orleans, generally showed no decreases in summer flow once the effect of precipitation was accounted for. Interestingly, Bull Creek, a tributary to South Fork Eel that is almost entirely within a California State Park and has almost no diversions, had large declines in summer flow. The declines in summer flow in Bull Creek may be caused by increased evapotranspiration from regenerating redwood forests or declining fog. The amount of fog along the California coast declined during the 20th century (Johnstone and Dawson 2010) and a recent study found that annual wood production in old-growth redwood trees on Bull Creek's alluvial flats was higher from 1970 to present than any time since at least 1750, likely due in part to reduced cloud cover and increased light availability (Sillett et al. 2013).

When significant trends were present for both flow alone and flow with the effects of precipitation accounted for, the percent of the flow trend not due to precipitation can be calculated. For unregulated sites only, Table 10 presents these results for the months of August through November, the months that had the largest number of significant trends.

Table 6. Summary of Mann-Kendall trend tests for 1953-2012 monthly and annual precipitation. Cells are shaded by the statistical significance of the trend ($p<0.05$ = dark grey, $0.05<p<0.10$ = light grey, and $p>0.10$ = white). Symbols indicate the per-year slope of trend as percent of median (▲▼ is >±1%, ↑↓ is 0.5-1.0%, and ↾↿ is 0.0-0.5%). Key to runoff types: G = groundwater, S = snowmelt, R/S = rain/snowmelt, R = rain. Key to hydrologic regulation ratings: 1= reservoir storage volume is 0-0.5% of precipitation, 2 = 0.5-5%, 3 = 5-15%, 4 = >15%.

Coho Population	Gage Name and Code	Runoff Type	Hydro Reg.	Trend for Annual & Monthly Precipitation												
				Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chetco	Chetco R (14400000)	R	1	↓	↓	↓	↓	↑	↑	↑	▼	▼	▼	↓	↓	↑
Smith	Smith R (11532500)	R	1	↓	↓	↓	↑	↑	↑	▲	↑	↓	▼	↓	↓	↑
Redwood	Redwood Cr Blue Lake (11481500)	R	1	↑	↓	↓	↓	↑	▲	▲	▲	↓	▼	↓	↓	↑
Redwood	Redwood Cr Orick (11482500)	R	1	↑	↓	↓	↓	↑	↑	▲	↑	↓	▼	↓	↓	↑
Redwood	Redwood Cr Accr: Orick - 299 (c11482500_11481500)	R	1	↑	↓	↓	↑	↑	↑	▲	↑	↓	▼	↓	↓	↑
Little	Little R (11481200)	R	1	↓	↓	↓	↓	▲	↑	▲	▲	↓	▼	↓	↓	↑
Mad	Mad R Arcata (11481000)	R	2	↓	↓	↓	↓	↑	▲	↑	▲	↓	▼	↓	↓	↑
Mattole	Mattole R Petrolia (11469000)	R	1	↓	↓	↑	↑	↑	↑	▲	▲	↓	▼	↓	↓	↑
Lwr Eel/Van Duz	Eel R Scotia (11477000)	R/S	2	↓	↓	↓	↑	↓	↑	▲	↑	▼	▼	↑	↓	↓
Lwr Eel/Van Duz	Van Duzen R (11478500)	R	1	↓	↓	↓	↑	↑	▲	▲	▲	↓	▼	↑	↓	↑
Lwr Eel/Van Duz, Main Eel, SF Eel	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)	R	1	↓	↓	↓	↑	↑	↑	▲	▲	↓	▼	↓	↓	↑
SF Eel	SF Eel R At Leggett (11475800)	R	1	↓	↓	↓	↓	↑	▲	▲	▲	▼	▼	↓	▼	↓
SF Eel	SF Eel R Nr Miranda (11476500)	R	1	↓	↓	↓	↑	↓	↑	▲	▲	↓	↓	↓	↓	↑
SF Eel	Bull Cr (11476600)	R	1	↓	↓	↑	↓	↑	▲	▲	▲	▼	▼	↓	▼	↑
SF Eel	Elder Cr (11475560)	R	1	↓	↓	▼	↓	↑	▲	▲	▲	▼	▼	▼	▼	↓
SF Eel	SF Eel R Accr: Miranda - Leggett (c11476500_11475800)	R	1	↓	↓	↑	↑	↑	▲	▲	▲	▼	▼	↓	▼	↓
Main Eel	Eel R Fort Seward (11475000)	R/S	2	↓	↓	↓	↑	↑	↑	▲	↓	▼	▼	↓	↓	↓
Upr Main Eel	Eel R Van Arsdale (11471500)	R/S	3	↓	↓	↑	↑	↓	↑	↑	↓	▼	↓	↑	↓	↑
Upr Main Eel	Eel R Scott Dam (11470500)	R/S	3	↓	↓	↑	↑	↓	↑	↑	↓	▼	↓	↑	↓	↑
Mid Fork Eel	MF Eel R (11473900)	R/S	1	↓	▼	↓	↓	↑	▲	▲	↓	▼	▼	↓	▼	↓
Mid Main Eel, Main Eel, NF Eel, SF Eel	Eel R Accr: Scotia - Van Ars (c11477000_11471500)	R	1	↓	↓	↓	↑	↓	↑	▲	↑	▼	▼	↓	↓	↓
Mid Main Eel, Main Eel, NF Eel, Mid Fork Eel, SF Eel	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)	R	1	↓	↓	↓	↑	↓	↑	▲	↓	▼	▼	↓	↓	↓
Mid Main Eel, Main Eel, NF Eel	Eel R Accr: Ft Sew - Van Ars - MF (c11475000_11471500_t1)	R	1	↓	↓	↓	↓	↑	▲	▲	▲	▼	▼	↓	▼	↓
Illinois	Illinois R Kerby (14377100)	R/S	1	↓	↓	↓	↓	↑	↑	▲	↑	▼	▼	↓	↓	↓
Illinois	Sucker Cr (14375100)	S	1	↓	↓	↓	↑	↑	▲	▲	↑	↓	▼	↑	↓	↓
Illinois	EF Illinois R (14372500)	R	1	↓	▼	↓	↓	↓	↑	↑	↑	▼	▼	↓	↓	↓
Illinois	Illinois R Accr: Kerby - EF - Sucker Cr (c14377100_14372500_t1)	R/S	1	↓	▼	↓	↓	↑	▲	▲	↑	▼	▼	↓	↓	↓
Mid Rogue/AppleG	Rogue R Grants Pass (14361500)	G	3	↑	↓	↓	↑	▲	↑	↑	↑	↓	▼	↓	↑	↑
Mid Rogue/AppleG	Rogue R Agness (14372300)	G	3	↓	↓	↓	↑	↑	↑	↑	↑	▼	▼	↓	↓	↑
Mid Rogue/AppleG	Rogue R Accr: Agness - Grants Pass (c14372300_14361500_t1)	R/S	1	↓	↓	↓	↓	↑	↑	↑	↓	↓	▼	↓	↓	↑
Mid Rogue/AppleG	Applegate R Copper (14362000)	S	4	↓	↓	↓	↑	↑	↑	↑	↑	↓	▼	↓	↑	↓
Mid Rogue/AppleG	Applegate R Applegate (14366000)	R/S	3	↓	↓	↓	↑	↑	↑	↑	↑	↓	▼	↓	↑	↓
Upr Rogue	Rogue R At Raygold (14359000)	G	3	↑	↓	↓	↑	▲	↑	↑	↑	↓	▼	↓	↑	↑
Upr Rogue	Rogue R Dodge Bridge (14339000)	G	4	↑	↓	↓	↑	↑	↑	↑	↑	↓	▼	↓	↑	↑
Upr Rogue	Rogue R Near Mcleod (14337600)	G	4	↑	↓	↓	↑	▲	▲	↑	↑	↓	▼	↓	↑	↑
Upr Rogue	Rogue R Blw Prospect (14330000)	G	1	↑	↑	↓	↑	↑	▲	▲	↑	↓	▼	↓	↓	↑
Upr Rogue	Rogue R Abv Prospect (14328000)	G	1	↑	↓	↓	↓	▲	▲	↑	▲	↓	↓	↑	↑	↓
Upr Rogue	SF Rogue R Nr Prospect (14332000)	S	1	↑	↓	↓	↑	↑	↑	↑	↑	↓	▼	↓	↑	↑
Upr Rogue	Elk Cr Trail (14338000)	R	1	↑	↓	↓	↑	↑	↑	↑	↑	↓	▼	↑	↑	↑
Upr Rogue	Big Butte Cr Near Mcleod (14337500)	G	2	↑	↓	↓	↑	↑	↑	↓	↑	↓	▼	↓	↑	↑
Upr Rogue	SF Big Butte Cr Ab Willow Cr (14335200)	G	1	↑	↓	↓	↑	↑	↑	↓	↑	↓	▼	↓	↑	↑

Coho Population	Gage Name and Code	Runoff Type	Hydro Reg.	Trend for Annual & Monthly Precipitation												
				Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upr Rogue	NF L Butte Cr Nr LakeCr (14343000)	G	4	↓	↑	↓	↑	↑	↑	↓	↑	↓	▼	↓	↑	↑
Upr Rogue	NF L Butte Cr At F L Nr LakeCr (14342500)	S	4	↓	↑	↓	↑	↑	↑	↓	↑	↓	▼	↓	↓	↑
Upr Rogue	Bear Cr At Medford (14357500)	R/S	3	↑	↓	↓	↑	▲	↑	↓	↑	↓	▼	↓	↑	↓
Upr Rogue	Rogue R Accr: Raygold - Mcleod (c14359000_14337600)	R/S	2	↑	↓	↓	↑	▲	▲	↑	↑	↓	▼	↓	↓	↑
Upr Rogue	Rogue R Accr: Raygold - Dodge Br (c14359000_14339000)	R	3	↓	↓	↓	↑	▲	↑	↑	↑	↓	▼	↓	↑	↓
Lwr Klamath	Klamath R Klamath (11530500)	S	3	↓	↓	↓	↓	↑	↑	↓	↑	↓	▼	↓	↓	↓
Mid Klamath	Klamath R Orleans (11523000)	S	3	↓	↓	↓	↑	↑	↑	↓	↑	↓	▼	↓	↓	↓
Mid Klamath, Lwr Klamath	Klamath R Accr: Klamath - Orl - TrinityR (c11530500_11523000_t1)	R	1	↓	↓	↓	↑	↑	↑	↑	↑	↓	▼	↓	↓	↑
Mid Klamath	Klamath R Accr: Orl - Sei - SalmR (c11523000_11520500_t2)	S	1	↓	▼	↓	↓	↑	↑	▲	↑	↓	▼	↓	↓	↓
Mid Klamath	Indian C (11521500)	R/S	1	↓	↓	↓	↓	↑	↑	▲	↑	↓	▼	↓	↓	↓
Upr Klamath	Klamath R Seiad Valley (11520500)	G	3	↓	↓	↓	↑	↑	↑	↓	↑	↓	▼	↓	↓	↓
Upr Klamath	Klamath R Iron Gate Dam (11516530)	G	4	↓	↓	↑	↑	▲	↑	↓	↑	▼	▼	↓	↓	↓
Upr Klamath	Klamath R JCB Pwrplnt (11510700)	G	4	↑	↑	↑	↑	▲	↑	↓	↑	▼	▼	↓	↓	↑
Upr Klamath	Klamath R Keno (11509500)	G	4	↓	↓	↓	↑	▲	↓	↓	↑	↓	▼	↓	↑	↑
Upr Klamath	Link R Klamath Falls (11507500)	S	4	↓	↓	↑	↑	▲	↑	↓	↓	▼	▼	↓	↓	↑
Upr Klamath	Klamath R Accr: Sei - IG - ShastR - ScottR (c11520500_11516530_t1)	S	1	↓	↓	↓	↓	↑	↑	↑	↑	↓	▼	↓	↓	↓
Upr Klamath	Klamath R Accr: Boyle - Keno (c11510700_11509500)	G	2	↓	↑	↓	↓	↑	↑	↓	↑	↓	▼	↓	↓	↑
Upr Klamath	Williamson R Blw Sprague R (11502500)	G	1	↓	↓	↓	↑	▲	↑	↓	↑	↓	↓	↓	↓	↑
Upr Klamath	Williamson R Klamath Agency (11493500)	S	1	↑	↑	↓	↑	↑	↑	↑	↓	↓	▼	↓	↓	↑
Upr Klamath	Williamson R Accr: Bl Sprg - SprgR - K Mrsh (c11502500_11493500_t1)	G	1	↓	↑	↓	↓	▲	↑	↑	↓	↓	▼	↓	↓	↑
Upr Klamath	Sprague R Chiloquin (11501000)	G	2	↓	↓	↓	↑	▲	↓	↓	↓	↓	↓	↓	↓	↑
Upr Klamath	Sprague R Beatty (11497500)	G	2	↓	↓	↑	↑	▲	↓	↓	↓	↓	▼	↓	↓	↑
Upr Klamath	Sprague R Accr: Chiloquin - Beatty (c11501000_11497500)	G	1	↓	↓	↑	↑	▲	↑	↓	↓	↓	▼	↓	↓	↑
Upr Klamath	Sprague R: Williamson R - Sprague (c11502500_11501000)	G	1	↓	↓	↓	↑	↑	↑	↓	↑	↓	▼	↓	↓	↑
Salmon	Salmon R (11522500)	S	1	↓	▼	↓	↓	↑	↑	↑	↑	▼	▼	↓	↓	↓
Scott	Scott R Ft Jones (11519500)	S	1	↓	↓	↓	↑	↑	↑	↑	↑	▼	▼	↑	↓	↓
Shasta	Shasta R Yreka (11517500)	G	3	↓	↓	↓	↑	↑	↑	↓	↑	▼	▼	↓	↓	↓
Lwr Trinity	Trinity R Hoopa (11530000)	R/S	4	↓	↓	↓	↓	↑	↑	↑	↑	▼	▼	↑	↓	↓
Lwr Trinity	Trinity R Burnt Ranch (11527000)	S	4	↓	↓	↓	↑	↑	↑	↑	↑	↓	▼	↑	↓	↑
Lwr Trinity	Trinity R Accr: Hoopa - Burnt Ranch - SF (c11530000_11527000_t1)	R/S	1	↓	↓	↓	↓	▲	▲	▲	↑	▼	▼	↓	▼	↓
Upr Trinity	Trinity R Lewiston (11525500)	S	4	↓	↓	↑	↑	↑	↑	↑	↑	▼	▼	↑	↓	↑
Upr Trinity	Trinity R Coffee Cr (11523200)	S	1	↓	↓	↓	↓	↑	↑	↑	↑	▼	▼	↓	↓	↑
Upr Trinity, Lwr Trinity	Trinity R Accr: Burnt Ranch - Lewiston (c11527000_11525500)	S	1	↓	↓	↓	↑	↑	↑	↑	▲	▼	▼	↑	↓	↑
Upr Trinity, Lwr Trinity	Trinity R Accr: Hoopa - Lewiston (c11530000_11525500)	R/S	1	↓	↓	↓	↓	↑	↑	↑	↑	▼	▼	↓	↓	↓
SF Trinity	SF Trinity Hyampom (11528700)	R/S	1	↓	▼	↓	↓	↑	▲	↑	↑	▼	▼	↓	▼	↓
% of hydrologic regulation rating 1 sites with **decreasing** trend (p<0.10)				**14**	**18**	**5**	**0**	**0**	**0**	**0**	**0**	**30**	**73**	**0**	**7**	**0**
% of hydrologic regulation rating 1 sites with **increasing** trend (p<0.10)				**0**	**0**	**0**	**0**	**30**	**25**	**20**	**25**	**0**	**0**	**0**	**0**	**0**
% of hydrologic reg. rating 2,3, or 4 sites with **decreasing** trend (p<0.10)				**0**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**12**	**66**	**0**	**0**	**0**
% of hydrologic reg. rating 2,3, or 4 sites with **increasing** trend (p<0.10)				**0**	**0**	**0**	**0**	**66**	**6**	**6**	**6**	**0**	**0**	**0**	**0**	**0**

Table 7. Summary of Mann-Kendall trend tests for 1953-2012 monthly and annual flow. Cells are shaded by the statistical significance of the trend ($p<0.05$ = dark grey, $0.05<p<0.10$ = light grey, and $p>0.10$ = white). Symbols indicate the per-year slope of trend as percent of median (▲▼ is >±1%, ↑↓ is 0.5-1.0%, and ↑↓ is 0.0-0.5%). Key to runoff types: G = groundwater, S = snowmelt, R/S = rain/snowmelt, R = rain. Key to hydrologic regulation ratings: 1= reservoir storage volume is 0-0.5% of precipitation, 2 = 0.5-5%, 3 = 5-15%, 4 = >15%.

Coho salmon Population	Gage Name and Code	Runoff Type	Hydro Reg.	Trend for Annual and Monthly Flow												
				Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chetco	Chetco R (14400000)	R	1	↓	↓	↓	↑	↑	▲	↑	↑	↑	↓	↓	↓	↑
Smith	Smith R (11532500)	R	1	↓	↓	↓	↑	↑	↑	↑	↑	↑	↓	↓	↓	↑
Redwood	Redwood Cr Blue Lake (11481500)	R	1	↓	↓	▼	↑	↑	↑	↓	↓	↓	▼	▼	▼	▼
Redwood	Redwood Cr Orick (11482500)	R	1	↓	↓	↓	↑	↑	↑	↑	↓	↓	▼	▼	▼	↓
Redwood	Redwood Cr Accr: Orick - 299 (c11482500_11481500)	R	1	↓	↓	↓	↑	↑	↑	↑	↑	↓	▼	▼	▼	↓
Little	Little R (11481200)	R	1	↓	↓	↓	↑	↑	↑	↑	↑	↓	↓	▼	↓	
Mad	Mad R Arcata (11481000)	R	2	↓	↓	↓	↑	↑	↑	↑	↑	↑	↑	↑	▼	↓
Mattole	Mattole R Petrolia (11469000)	R	1	↓	↓	↓	↑	↓	↑	↑	↓	↓	▼	↓	▼	↓
Lwr Eel/Van Duz	Eel R Scotia (11477000)	R/S	2	↓	↓	↓	↑	↓	↑	↓	↓	↓	↓	↓	▼	↓
Lwr Eel/Van Duz	Van Duzen R (11478500)	R	1	↓	↓	↓	↑	↑	↑	↓	↓	↓	▼	↓	▼	↓
Lwr Eel/Van Duz, Main Eel, SF Eel	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)	R	1	↓	↓	▼	↓	↑	↑	↓	↓	↓	▼	▼	▼	↓
SF Eel	SF Eel R At Leggett (11475800)	R	1	▼	▼	↓	↓	↓	↑	↑	↓	↓	▼	↓	▼	▼
SF Eel	SF Eel R Nr Miranda (11476500)	R	1	↓	↓	↓	↑	↓	↑	↓	↓	▼	▼	↓	▼	↓
SF Eel	Bull Cr (11476600)	R	1	↓	↓	↓	↑	↑	↑	↑	↓	▼	▼	▼	▼	↓
SF Eel	Elder Cr (11475560)	R	1	↓	↓	↓	↓	↑	▲	↑	↑	↓	▼	↓	▼	▼
SF Eel	SF Eel R Accr: Miranda - Leggett (c11476500_11475800)	R	1	▼	▼	↓	↓	↓	↑	↓	↓	▼	▼	▼	▼	▼
Main Eel	Eel R Fort Seward (11475000)	R/S	2	↓	↓	↓	↑	↑	↑	↑	↑	↓	↓	↓	▼	↓
Upr Main Eel	Eel R Van Arsdale (11471500)	R/S	3	↓	↓	↓	↑	↑	▲	▲	▲	▲	▲	▲	▲	▲
Upr Main Eel	Eel R Scott Dam (11470500)	R/S	3	↓	↓	↓	↑	↑	↑	↓	↓	↓	↓	↓	↓	↓
Mid Fork Eel	MF Eel R (11473900)	R/S	1	↓	▼	↓	↑	↑	↑	↑	↓	↓	▼	↓	▼	↓
Mid Main Eel, Main Eel, NF Eel, SF Eel	Eel R Accr: Scotia - Van Ars (c11477000_11471500)	R	1	↓	↓	↓	↑	↓	↓	↓	↓	↓	▼	↓	▼	↓
Mid Main Eel, Main Eel, NF Eel, Mid Fork Eel, SF Eel	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)	R	1	↓	↓	↓	↑	↓	↑	↓	↓	↓	▼	↓	▼	↓
Mid Main Eel, Main Eel, NF Eel	Eel R Accr: Ft Sew - Van Ars - MF (c11475000_11471500_t1)	R	1	↓	↓	↓	↑	↑	▲	↑	↑	▼	▼	▼	▼	↓
Illinois	Illinois R Kerby (14377100)	R/S	1	↓	↓	↓	↑	↑	↑	↑	↑	↓	↓	▼	▼	↓
Illinois	Sucker Cr (14375100)	S	1	↓	↓	↓	↑	↑	↑	↑	↓	↓	↓	↓	↓	↓
Illinois	EF Illinois R (14372500)	R	1	↓	↓	↓	↑	↓	↓	↓	↓	↓	↓	↓	▼	↓
Illinois	Illinois R Accr: Kerby - EF - Sucker Cr (c14377100_14372500_t1)	R/S	1	↓	↓	↓	↑	↑	↑	▲	▲	▼	▼	▼	▼	↓
Mid Rogue/AppleG	Rogue R Grants Pass (14361500)	G	3	↓	↓	▼	↓	↓	↑	↑	↑	▲	↑	↓	↓	↓
Mid Rogue/AppleG	Rogue R Agness (14372300)	G	3	↓	↓	▼	↓	↓	↑	↑	▲	▲	↑	↑	↓	↓
Mid Rogue/AppleG	Rogue R Accr: Agness - Grants Pass (c14372300_14361500_t1)	R/S	1	↓	↓	↓	↓	↑	↑	↑	▲	↑	↑	↑	▼	↓
Mid Rogue/AppleG	Applegate R Copper (14362000)	S	4	↓	↓	▼	▼	▼	↓	↑	▲	▲	▲	▲	↑	↓
Mid Rogue/AppleG	Applegate R Applegate (14366000)	R/S	3	↓	↓	▼	▼	▼	↓	↑	▲	▲	▲	▲	↑	↓
Upr Rogue	Rogue R At Raygold (14359000)	G	3	↓	↓	▼	↓	↓	↓	↑	↑	▲	↑	↓	↓	↓
Upr Rogue	Rogue R Dodge Bridge (14339000)	G	4	↓	↓	▼	↓	↓	↓	↑	↑	▲	↑	↓	↓	↓
Upr Rogue	Rogue R Near Mcleod (14337600)	G	4	↓	↓	▼	↓	↓	↑	↑	↑	▲	↑	↓	↓	↓
Upr Rogue	Rogue R Blw Prospect (14330000)	G	1	↓	↓	↓	↑	↑	↓	↑	↓	↓	↓	↓	↓	↓
Upr Rogue	Rogue R Abv Prospect (14328000)	G	1	↓	↓	↓	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓
Upr Rogue	SF Rogue R Nr Prospect (14332000)	S	1	↑	↑	↓	↑	↑	↓	↓	▲	▲	▲	▲	▲	▲
Upr Rogue	Elk Cr Trail (14338000)	R	1	↓	↓	↓	↓	↓	↓	↑	↑	↓	↓	↓	↓	↑
Upr Rogue	Big Butte Cr Near Mcleod (14337500)	G	2	▼	▼	▼	↓	↓	↓	↓	↓	↓	↓	↓	▼	▼
Upr Rogue	SF Big Butte Cr Ab Willow Cr (14335200)	G	1	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Upr Rogue	NF L Butte Cr Nr LakeCr (14343000)	G	4	↓	↓	↓	↓	↑	↓	↓	↓	↓	↑	↑	↓	↓
Upr Rogue	NF L Butte Cr At F L Nr LakeCr (14342500)	S	4	↓	↓	↓	↓	↓	↓	▼	▼	↓	↑	▲	↓	↓
Upr Rogue	Bear Cr At Medford (14357500)	R/S	3	↓	↓	▼	↓	↑	↓	↓	↑	↑	↑	↑	↓	↓
Upr Rogue	Rogue R Accr: Raygold - Mcleod (c14359000_14337600)	R/S	2	↓	▼	↓	↑	↑	↓	▼	▼	▼	↓	↓	▼	↓

Coho salmon Population	Gage Name and Code	Runoff Type	Hydro Reg.	Trend for Annual and Monthly Flow												
				Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upr Rogue	Rogue R Accr: Raygold - Dodge Br (c14359000_14339000)	R	3	↓	▼	▼	↓	↑	↓	▼	▼	▼	↓	↓	↓	↓
Lwr Klamath	Klamath R Klamath (11530500)	S	3	↓	↓	▼	↓	↓	↓	↓	↑	↓	↓	↓	↓	↓
Mid Klamath	Klamath R Orleans (11523000)	S	3	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	▼	↓
Mid Klamath, Lwr Klamath	Klamath R Accr: Klamath - Orl - TrinityR (c11530500_11523000_t1)	R	1	↓	↓	↓	↑	↑	↑	↑	↑	↓	↓	↑	↓	↑
Mid Klamath	Klamath R Accr: Orl - Sei - SalmR (c11523000_11520500_t2)	S	1	↓	↓	↓	↑	↓	↓	↓	↓	↑	↑	↓	↓	↓
Mid Klamath	Indian C (11521500)	R/S	1	↓	↑	↓	↑	↑	↓	↓	↓	↓	↓	↓	↓	↑
Upr Klamath	Klamath R Seiad Valley (11520500)	G	3	↓	↓	▼	↓	↓	↓	↓	↓	↓	↓	▼	▼	▼
Upr Klamath	Klamath R Iron Gate Dam (11516530)	G	4	↓	▼	▼	↓	↓	↑	▲	↑	↓	↓	↓	▼	▼
Upr Klamath	Klamath R JCB Pwrplnt (11510700)	G	4	↓	▼	↓	↓	↑	↑	▲	↑	↑	↓	▼	▼	▼
Upr Klamath	Klamath R Keno (11509500)	G	4	▼	▼	▼	↓	↓	↓	↑	↑	↓	▼	▼	▼	▼
Upr Klamath	Link R Klamath Falls (11507500)	S	4	↓	▼	▼	↓	↓	▲	▲	▲	▲	↑	↓	▼	▼
Upr Klamath	Klamath R Accr: Sei - IG - ShastR - ScottR (c11520500_11516530_t1)	S	1	↓	↓	▼	↓	↓	↓	↓	↓	↓	↓	↓	▼	▼
Upr Klamath	Klamath R Accr: Boyle - Keno (c11510700_11509500)	G	2	↑	↑	↑	↑	↑	↑	↑	↓	↓	↑	↑	↑	▲
Upr Klamath	Williamson R Blw Sprague R (11502500)	G	1	↓	↓	▼	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Upr Klamath	Williamson R Klamath Agency (11493500)	S	1	▼	▼	▼	▼	▼	▼	▼	▼	[Median Aug-Oct flow is zero]			▼	▼
Upr Klamath	Williamson R Accr: Bl Sprg - SprgR - K Mrsh (c11502500_11493500_t1)	G	1	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Upr Klamath	Sprague R Chiloquin (11501000)	G	2	↓	↓	↓	↓	↓	↓	↓	▼	▼	▼	↓	↓	↓
Upr Klamath	Sprague R Beatty (11497500)	G	2	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Upr Klamath	Sprague R Accr: Chiloquin - Beatty (c11501000_11497500)	G	1	↓	↓	↓	↓	↓	↓	↓	▼	▼	▼	▼	↓	↓
Upr Klamath	Sprague R: Williamson R - Sprague (c11502500_11501000)	G	1	↓	▼	▼	▼	▼	▼	↓	↓	↓	↓	↓	↓	▼
Salmon	Salmon R (11522500)	S	1	↓	↓	↓	↑	↑	↓	↓	↑	↓	↓	↓	↓	↓
Scott	Scott R Ft Jones (11519500)	S	1	↓	↓	▼	↓	↓	↓	↓	↓	▼	▼	▼	▼	↓
Shasta	Shasta R Yreka (11517500)	G	3	↓	↓	↓	↓	↑	↓	↓	↑	↓	↓	↓	↓	↓
Lwr Trinity	Trinity R Hoopa (11530000)	R/S	4	↓	↓	↓	↑	↓	↑	↑	↑	↑	▲	↑	↓	↓
Lwr Trinity	Trinity R Burnt Ranch (11527000)	S	4	↑	↑	↓	↓	↓	▲	▲	▲	▲	▲	↑	↓	↓
Lwr Trinity	Trinity R Accr: Hoopa - Burnt Ranch - SF (c11530000_11527000_t1)	R/S	1	↓	↓	↓	↑	↑	↑	↑	↑	↑	↓	↓	↓	↓
Upr Trinity	Trinity R Lewiston (11525500)	S	4	▲	↓	↓	↓	↑	▲	▲	▲	▲	▲	▲	↑	↑
Upr Trinity	Trinity R Coffee Cr (11523200)	S	1	↑	↓	↓	↑	↑	↑	↓	↑	↑	↓	↑	↓	↓
Upr Trinity, Lwr Trinity	Trinity R Accr: Burnt Ranch - Lewiston (c11527000_11525500)	S	1	↓	↑	↓	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓
Upr Trinity, Lwr Trinity	Trinity R Accr: Hoopa - Lewiston (c11530000_11525500)	R/S	1	↓	↓	↓	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓
SF Trinity	SF Trinity Hyampom (11528700)	R/S	1	↓	▼	↓	↓	↑	↑	↑	↓	↓	↓	↓	▼	↓
% of hydrologic regulation rating 1 sites with **decreasing** trend (p<0.10)				**23**	**14**	**34**	**9**	**9**	**9**	**14**	**11**	**39**	**66**	**32**	**39**	**14**
% of hydrologic regulation rating 1 sites with **increasing** trend (p<0.10)				**0**	**0**	**0**	**7**	**0**	**2**	**2**	**5**	**5**	**2**	**2**	**2**	**0**
% of hydrologic regulation rating 2,3, or 4 sites with **decreasing** trend (p<0.10)				**22**	**16**	**66**	**12**	**9**	**3**	**6**	**19**	**31**	**34**	**47**	**50**	**28**
% of hydrologic regulation rating 2,3, or 4 sites with **increasing** trend (p<0.10)				**6**	**3**	**3**	**3**	**3**	**16**	**25**	**41**	**38**	**38**	**22**	**6**	**3**

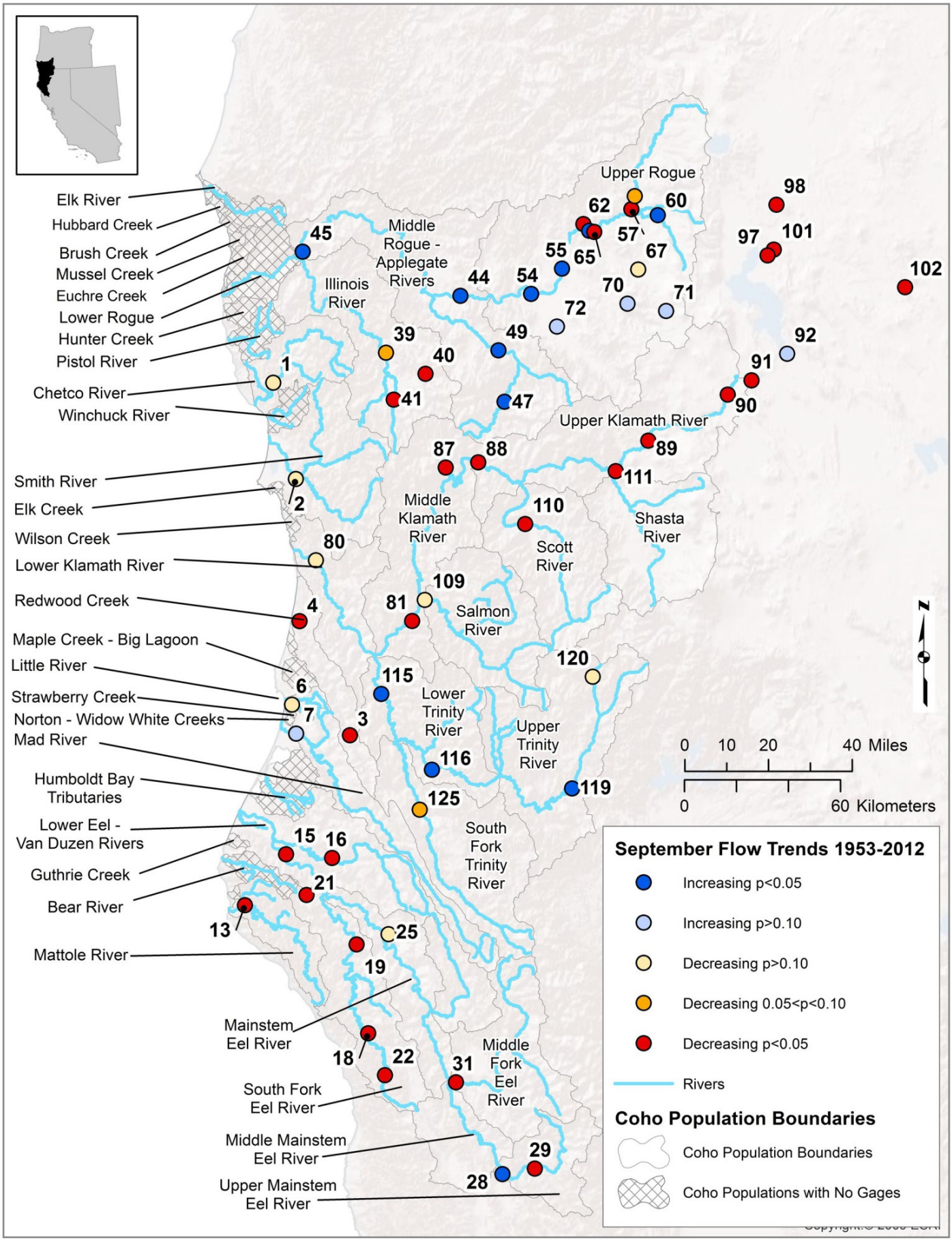

Figure 10. Map of September streamflow trends for 1953-2012 for stream gages within the SONCC coho salmon ESU.

Table 8. Summary of Mann-Kendall trend tests for 1953-2012 for the runoff coefficient, baseflow index, streamflow centroid, and the timing and magnitude of the 7-day minimum flow, 30-day minimum flow, and 90-day minimum flow. Cells are shaded by the statistical significance of the trend ($p<0.05$ = dark grey, $0.05<p<0.10$ = light grey, and $p>0.10$ = white). Symbols indicate the per-year slope of trend as percent of median (▲▼ is >±1%, ↑↓ is 0.5-1.0%, and ↾↿ is 0.0-0.5%), except for the four timing metrics (far right columns) where the units are days per year rather than percent per year. Key to runoff types: G = groundwater, S = snowmelt, R/S = rain/snowmelt, R = rain. Key to hydrologic regulation ratings: 1= reservoir storage volume is 0-0.5% of precipitation, 2 = 0.5-5%, 3 = 5-15%, 4 = >15%. Baseflow index and 7-day minimum flow were not calculated for accretions.

Coho salmon Population	Gage Name and Code	Runoff Type	Hydro Reg.	Runoff Coefficient	Baseflow Index	7, 30, 90-day Low Flow						Streamflow Centroid
						Magnitude			Timing			
						7d	30d	90d	7d	30d	90d	
Chetco	Chetco R (14400000)	R	1	↑	↑	↑	↑	↑	↑	↑	↑	↑
Smith	Smith R (11532500)	R	1	↓	↑	↓	↓	↓	↑	↑	↑	↑
Redwood	Redwood Cr Blue Lake (11481500)	R	1	↓	▼	▼	▼	▼	↑	↑	↑	↑
Redwood	Redwood Cr Orick (11482500)	R	1	↓	▼	▼	▼	▼	↑	↑	↑	↑
Redwood	Redwood Cr Accr: Orick - 299 (c11482500_11481500)	R	1	↓			▼	▼		↑	↑	↑
Little	Little R (11481200)	R	1	↓	↓	↓	↓	↓	↑	↑	↑	↑
Mad	Mad R Arcata (11481000)	R	2	↓	▲	↑	↑	↑	↓	↓	↑	↑
Mattole	Mattole R Petrolia (11469000)	R	1	↓	↓	↓	↓	↓	↑	↑	↑	↑
Lwr Eel/Van Duz	Eel R Scotia (11477000)	R/S	2	↓	↓	↓	↓	↓	↑	↑	↓	↑
Lwr Eel/Van Duz	Van Duzen R (11478500)	R	1	↓	↓	↓	↓	▼	↓	↑	↑	↑
Lwr Eel/Van Duz, Main Eel, SF Eel	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)	R	1	↓			↓	↓		↑	↑	↑
SF Eel	SF Eel R At Leggett (11475800)	R	1	↓	↑	▼	↓	↓	↑	↑	↑	↑
SF Eel	SF Eel R Nr Miranda (11476500)	R	1	↓	↓	▼	▼	▼	↑	↑	↑	↑
SF Eel	Bull Cr (11476600)	R	1	↓	▼	▼	▼	▼	↓	↑	↑	↑
SF Eel	Elder Cr (11475560)	R	1	↑	↓	↓	↓	↓	↑	↑	↑	↑
SF Eel	SF Eel R Accr: Miranda - Leggett (c11476500_11475800)	R	1	↓			▼	▼		↑	↑	↑
Main Eel	Eel R Fort Seward (11475000)	R/S	2	↑	↓	↓	↓	↓	↓	↓	↑	↑
Upr Main Eel	Eel R Van Arsdale (11471500)	R/S	3	↑	▲	▲	▲	▲	▼	↓	↓	↑
Upr Main Eel	Eel R Scott Dam (11470500)	R/S	3	↓	▲	↑	↑	↓	▲	▲	↑	↑
Mid Fork Eel	MF Eel R (11473900)	R/S	1	↓	▼	↓	↓	▼	↑	↑	↑	↑
Mid Main Eel, Main Eel, NF Eel, SF Eel	Eel R Accr: Scotia - Van Ars (c11477000_11471500)	R	1	↓			▼	▼		↑	↑	↑
Mid Main Eel, Main Eel, NF Eel, Mid Fork Eel, SF Eel	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)	R	1	↓			▼	▼		↑	↑	↑
Mid Main Eel, Main Eel, NF Eel	Eel R Accr: Ft Sew - Van Ars - MF (c11475000_11471500_t1)	R	1	↑			▼	▼		↑	↑	↑
Illinois	Illinois R Kerby (14377100)	R/S	1	↑	↓	↓	↓	↓	↑	↑	↑	↑
Illinois	Sucker Cr (14375100)	S	1	↓	↓	↓	↓	↓	↓	↓	↓	↑
Illinois	EF Illinois R (14372500)	R	1	↓	↑	↓	↓	↓	↓	↑	↑	↑
Illinois	Illinois R Accr: Kerby - EF - Sucker Cr (c14377100_14372500_t1)	R/S	1	↑			▼	▼		↑	↑	↑
Mid Rogue/AppleG	Rogue R Grants Pass (14361500)	G	3	↓	↑	↑	↑	↑	↑	▲	▲	↑
Mid Rogue/AppleG	Rogue R Agness (14372300)	G	3	↓	▲	↑	↑	↑	↑	↑	↑	↑
Mid Rogue/AppleG	Rogue R Accr: Agness - Grants Pass (c14372300_14361500_t1)	R/S	1	↓			▲	↑		↑	↑	↑
Mid Rogue/AppleG	Applegate R Copper (14362000)	S	4	↓	▲	▲	▲	▲	▼	▼	↓	↑
Mid Rogue/AppleG	Applegate R Applegate (14366000)	R/S	3	↓	▲	▲	▲	▲	↓	↓	↓	↑
Upr Rogue	Rogue R At Raygold (14359000)	G	3	↓	↑	↓	↓	↑	↑	↑	↑	↑
Upr Rogue	Rogue R Dodge Bridge (14339000)	G	4	↓	↑	↓	↓	↑	↑	↑	↑	↑
Upr Rogue	Rogue R Near Mcleod (14337600)	G	4	↓	↑	↓	↓	↑	↓	↓	↑	↑
Upr Rogue	Rogue R Blw Prospect (14330000)	G	1	↓	↓	↓	↓	↓	↓	↓	↓	↑
Upr Rogue	Rogue R Abv Prospect (14328000)	G	1	↓	↓	↓	↓	↓	↓	↓	↓	↓
Upr Rogue	SF Rogue R Nr Prospect (14332000)	S	1	↑	▲	▲	▲	▲	↓	↓	↓	↓
Upr Rogue	Elk Cr Trail (14338000)	R	1	↓	↓	↓	↓	↓	↑	↑	↑	↑
Upr Rogue	Big Butte Cr Near Mcleod (14337500)	G	2	▼	↑	↓	↓	↓	↑	↑	↓	↑
Upr Rogue	SF Big Butte Cr Ab Willow Cr (14335200)	G	1	↓	↓	↓	↓	↓	↑	↑	↑	↑
Upr Rogue	NF L Butte Cr Nr LakeCr (14343000)	G	4	↓	▲	↑	↑	↑	↑	↑	↑	↓

Coho salmon Population	Gage Name and Code	Runoff Type	Hydro Reg.	Runoff Coefficient	Baseflow Index	7, 30, 90-day Low Flow						Streamflow Centroid
						Magnitude			Timing			
						7d	30d	90d	7d	30d	90d	
Upr Rogue	NF L Butte Cr At F L Nr LakeCr (14342500)	S	4	↓	▲	↓	↓	↓	↑	↓	↓	↓
Upr Rogue	Bear Cr At Medford (14357500)	R/S	3	↓	↑	↑	↑	↑	↑	▲	↑	↑
Upr Rogue	Rogue R Accr: Raygold - Mcleod (c14359000_14337600)	R/S	2	↓			▼	▼		↑	↓	↑
Upr Rogue	Rogue R Accr: Raygold - Dodge Br (c14359000_14339000)	R	3	↓			▲	▼		↓	↓	↑
Lwr Klamath	Klamath R Klamath (11530500)	S	3	↓	↑	↓	↓	↓	↑	↑	↑	↑
Mid Klamath	Klamath R Orleans (11523000)	S	3	↓	↑	↓	↓	↓	↑	↑	↑	↑
Mid Klamath, Lwr Klamath	Klamath R Accr: Klamath - Orl - TrinityR (c11530500_11523000_t1)	R	1	↓			↑	↑		↓	↓	↑
Mid Klamath	Klamath R Accr: Orl - Sei - SalmR (c11523000_11520500_t2)	S	1	↑			↑	↑		↑	↑	↑
Mid Klamath	Indian C (11521500)	R/S	1	↑	↓	↓	↓	↓	↓	↑	↓	↑
Upr Klamath	Klamath R Seiad Valley (11520500)	G	3	↓	↑	↓	↓	↓	↑	↑	↑	↑
Upr Klamath	Klamath R Iron Gate Dam (11516530)	G	4	↓	▲	↑	↑	↑	↑	↑	↑	↑
Upr Klamath	Klamath R JCB Pwrplnt (11510700)	G	4	↓	▲	↑	↑	↑	↑	↑	↑	↑
Upr Klamath	Klamath R Keno (11509500)	G	4	▼	↑	↓	↑	↑	↑	↑	↑	↑
Upr Klamath	Link R Klamath Falls (11507500)	S	4	↓	▲	▲	▲	↑	▲	▲	↑	▲
Upr Klamath	Klamath R Accr: Sei - IG - ShastR - ScottR (c11520500_11516530_t1)	S	1	↓			↓	↓		↓	↑	↑
Upr Klamath	Klamath R Accr: Boyle - Keno (c11510700_11509500)	G	2	↑			▲	▲		↑	↑	↓
Upr Klamath	Williamson R Blw Sprague R (11502500)	G	1	↓	↑	↓	↓	↓	↑	↑	↓	↑
Upr Klamath	Williamson R Klamath Agency (11493500)	S	1	▼					↓	↑	↑	↑
Upr Klamath	Williamson R Accr: Bl Sprg - SprgR - K Mrsh (c11502500_11493500_t1)	G	1	↓			↓	↓		↓	▼	↑
Upr Klamath	Sprague R Chiloquin (11501000)	G	2	↓	↓	▼	▼	▼	↑	↑	↓	↓
Upr Klamath	Sprague R Beatty (11497500)	G	2	↓	↓	↓	↓	↓	↓	↓	↓	↑
Upr Klamath	Sprague R Accr: Chiloquin - Beatty (c11501000_11497500)	G	1	↓			▼	▼		↑	↓	↓
Upr Klamath	Sprague R: Williamson R - Sprague (c11502500_11501000)	G	1	↓			↓	↓		↓	↓	↑
Salmon	Salmon R (11522500)	S	1	↑	↑	↓	↓	↓	↑	↑	↓	↑
Scott	Scott R Ft Jones (11519500)	S	1	↓	▼	▼	▼	▼	↓	↓	↓	↑
Shasta	Shasta R Yreka (11517500)	G	3	↓	▲	↑	↑	↑	↑	↑	↑	↑
Lwr Trinity	Trinity R Hoopa (11530000)	R/S	4	↓	▲	↑	↑	↑	↑	↑	↑	↑
Lwr Trinity	Trinity R Burnt Ranch (11527000)	S	4	↑	▲	▲	▲	▲	↑	▲	↑	↑
Lwr Trinity	Trinity R Accr: Hoopa - Burnt Ranch - SF (c11530000_11527000_t1)	R/S	1	↓			↑	↑		↑	↑	↑
Upr Trinity	Trinity R Lewiston (11525500)	S	4	▲	↓	↑	↑	↑	↓	↓	↓	↑
Upr Trinity	Trinity R Coffee Cr (11523200)	S	1	↑	↓	↓	↓	↓	↓	↓	↓	↑
Upr Trinity, Lwr Trinity	Trinity R Accr: Burnt Ranch - Lewiston (c11527000_11525500)	S	1	↓			↓	↓		↓	↑	↑
Upr Trinity, Lwr Trinity	Trinity R Accr: Hoopa - Lewiston (c11530000_11525500)	R/S	1	↓			↓	↓		↓	↓	↑
SF Trinity	SF Trinity Hyampom (11528700)	R/S	1	↑	↓	↓	↓	↓	↓	↓	↑	↑
% of hydrologic regulation rating 1 sites with **decreasing** trend (p<0.10)				**43**	**37**	**48**	**48**	**43**	**7**	**2**	**7**	**0**
% of hydrologic regulation rating 1 sites with **increasing** trend (p<0.10)				**5**	**4**	**4**	**2**	**2**	**4**	**11**	**7**	**39**
% of hydrologic regulation rating 2,3, or 4 sites with **decreasing** trend (p<0.10)				**44**	**7**	**14**	**22**	**22**	**7**	**3**	**3**	**6**
% of hydrologic regulation rating 2,3, or 4 sites with **increasing** trend (p<0.10)				**9**	**69**	**41**	**44**	**41**	**45**	**47**	**47**	**62**

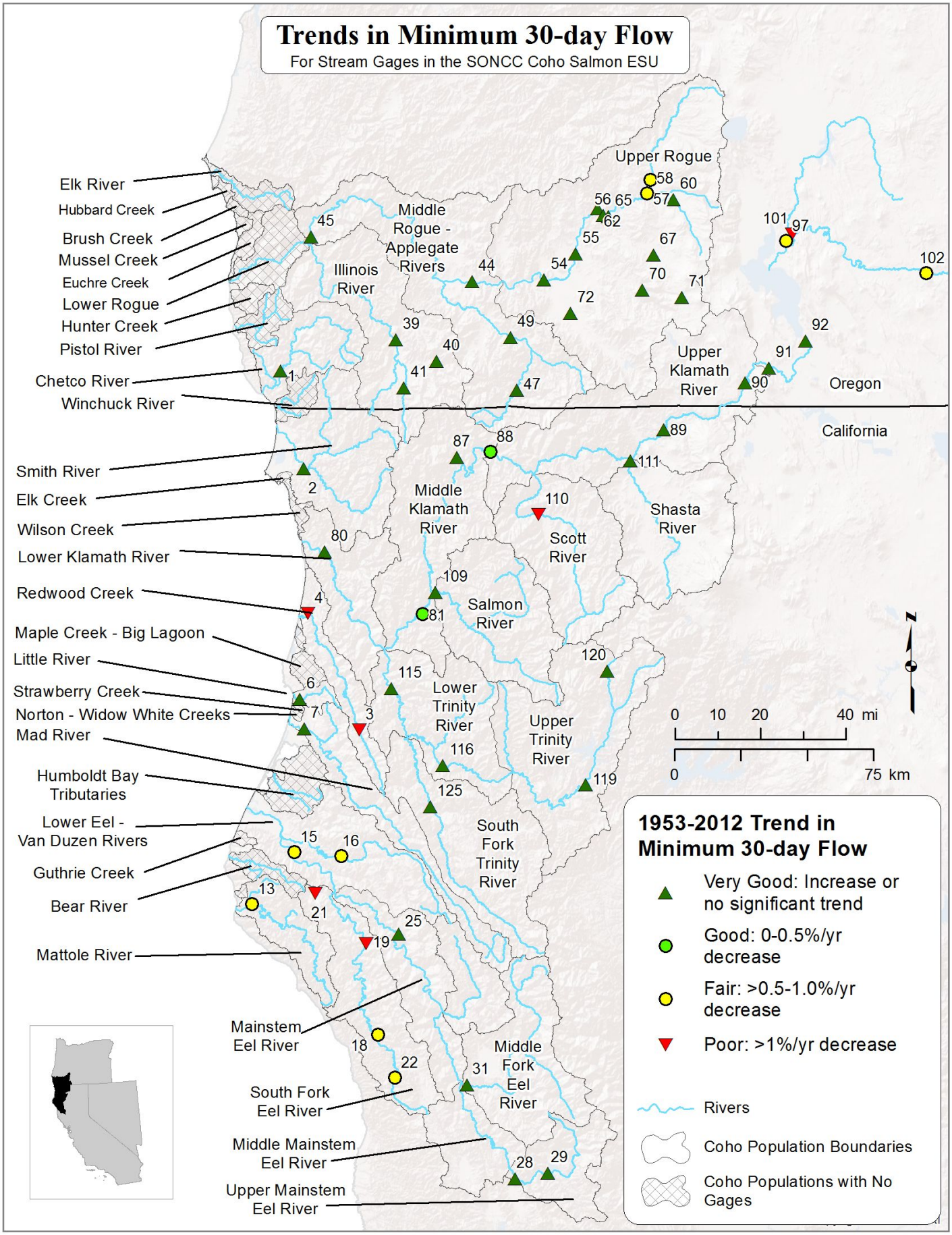

Figure 11. Map of 1953-2012 trends in minimum 30-day streamflow. Gages are color-coded according to the rules in Table 2.

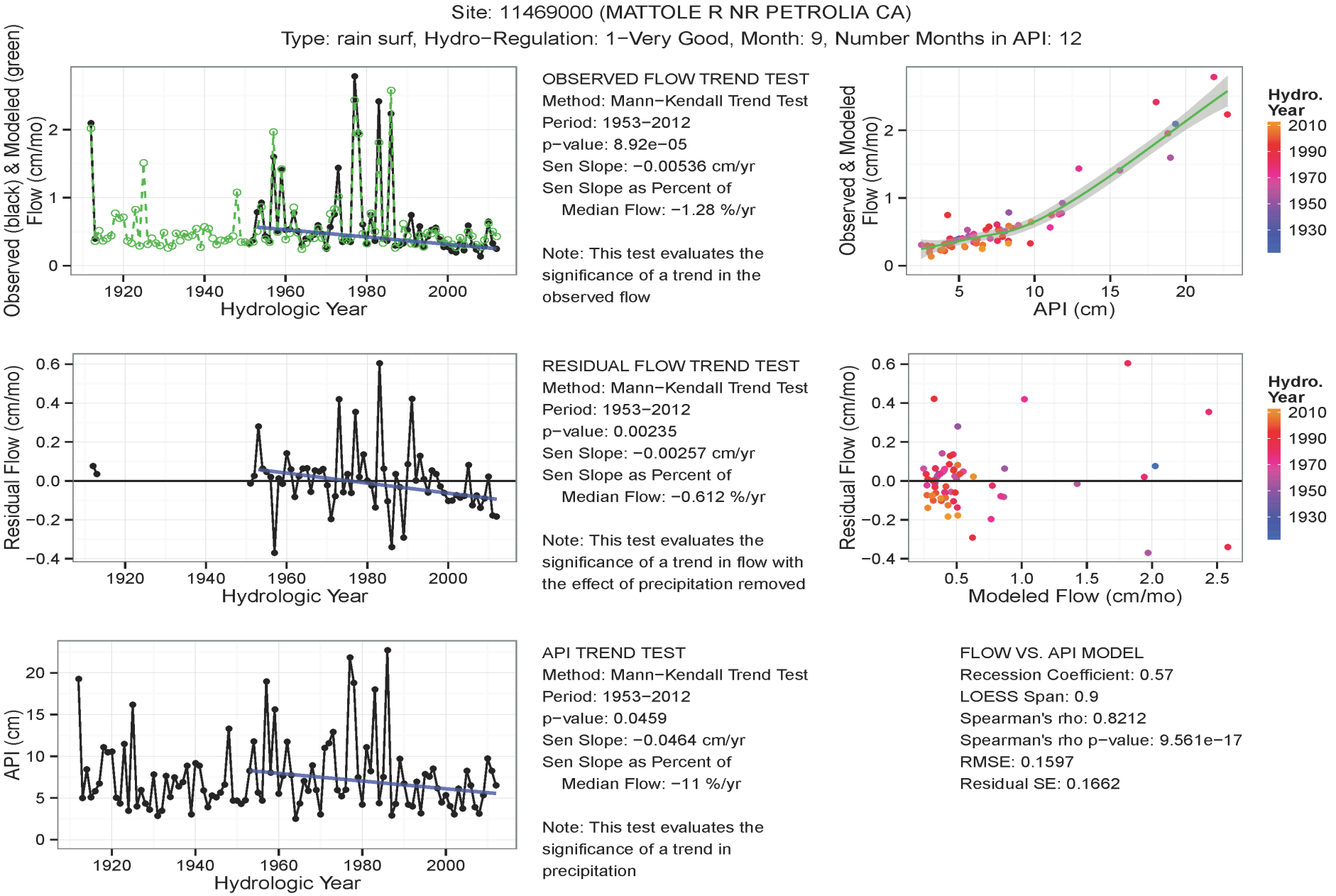
Site: 11469000 (MATTOLE R NR PETROLIA CA)
Type: rain surf, Hydro−Regulation: 1−Very Good, Month: 9, Number Months in API: 12
Observed (black) & Modeled (green) Flow (cm/mo)
Hydrologic Year
OBSERVED FLOW TREND TEST
Method: Mann−Kendall Trend Test
Period: 1953−2012
p−value: 8.92e−05
Sen Slope: −0.00536 cm/yr
Sen Slope as Percent of
Median Flow: −1.28 %/yr
Note: This test evaluates the significance of a trend in the observed flow
Observed & Modeled Flow (cm/mo)
API (cm)
Hydro. Year
2010
1990
1970
1950
1930
Residual Flow (cm/mo)
RESIDUAL FLOW TREND TEST
Method: Mann−Kendall Trend Test
Period: 1953−2012
p−value: 0.00235
Sen Slope: −0.00257 cm/yr
Sen Slope as Percent of
Median Flow: −0.612 %/yr
Note: This test evaluates the significance of a trend in flow with the effect of precipitation removed
Modeled Flow (cm/mo)
API (cm)
API TREND TEST
Method: Mann−Kendall Trend Test
Period: 1953−2012
p−value: 0.0459
Sen Slope: −0.0464 cm/yr
Sen Slope as Percent of
Median Flow: −11 %/yr
Note: This test evaluates the significance of a trend in precipitation
FLOW VS. API MODEL
Recession Coefficient: 0.57
LOESS Span: 0.9
Spearman's rho: 0.8212
Spearman's rho p−value: 9.561e−17
RMSE: 0.1597
Residual SE: 0.1662

Figure 12. Results of Mann-Kendall 1953–2012 trend tests for flow, flow residual, and API at Mattole River at Petrolia (gage 1146900) for the month of September (left and middle panels). Right panel shows a scatterplot of flow vs. API using the entire period of record (not just 1953–2012), with best-fit LOESS model overlaid. Residual is the error (i.e., observed minus modeled) from the flow vs. API model. Y-axis units for all graphs are centimeters per month (i.e., water volume divided by watershed area).

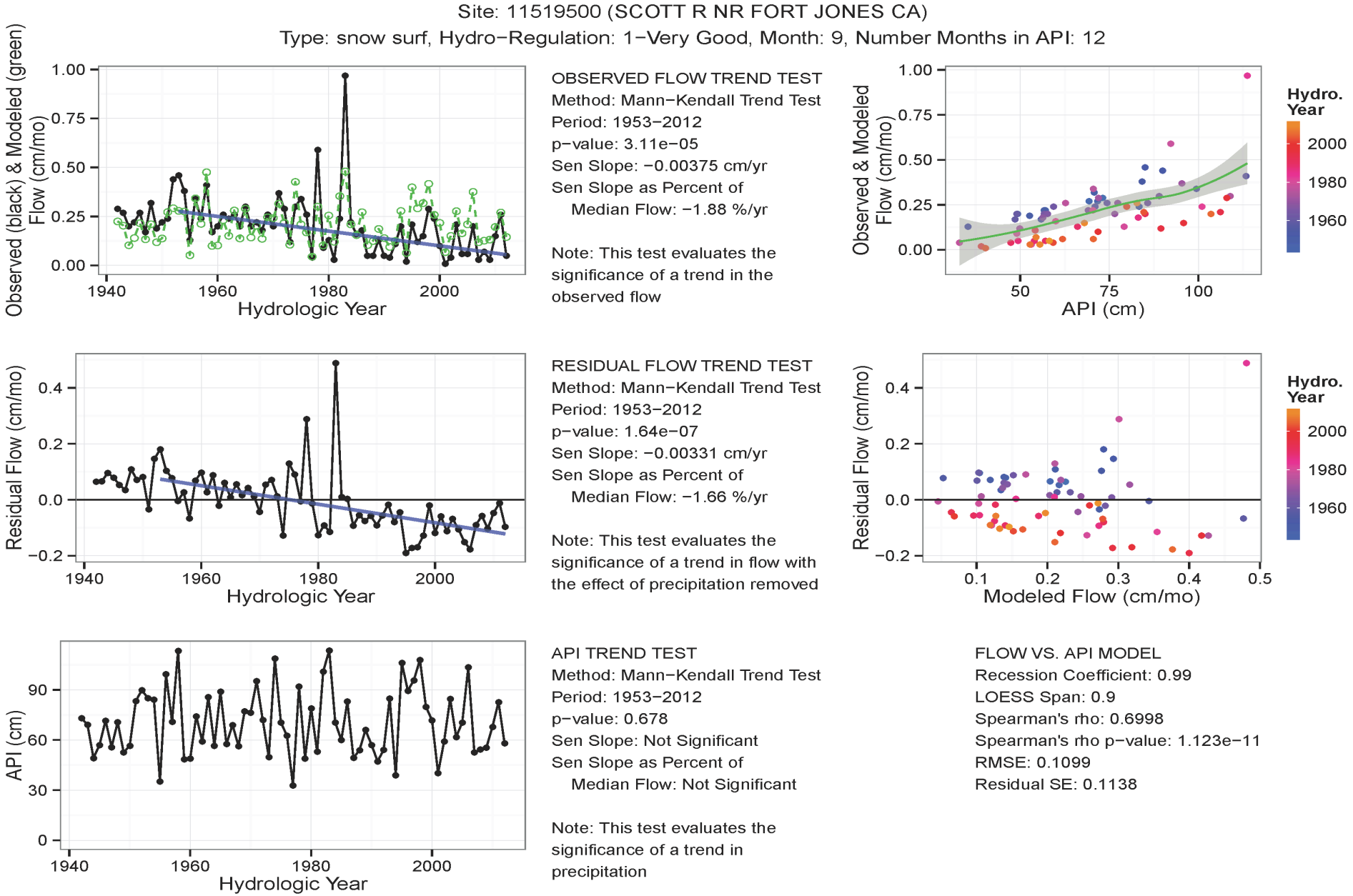
Site: 11519500 (SCOTT R NR FORT JONES CA)
Type: snow surf, Hydro−Regulation: 1−Very Good, Month: 9, Number Months in API: 12
Observed (black) & Modeled (green) Flow (cm/mo)
Hydrologic Year
OBSERVED FLOW TREND TEST
Method: Mann−Kendall Trend Test
Period: 1953−2012
p−value: 3.11e−05
Sen Slope: −0.00375 cm/yr
Sen Slope as Percent of
Median Flow: −1.88 %/yr
Note: This test evaluates the significance of a trend in the observed flow
Observed & Modeled Flow (cm/mo)
API (cm)
Hydro. Year
Residual Flow (cm/mo)
RESIDUAL FLOW TREND TEST
Method: Mann−Kendall Trend Test
Period: 1953−2012
p−value: 1.64e−07
Sen Slope: −0.00331 cm/yr
Sen Slope as Percent of
Median Flow: −1.66 %/yr
Note: This test evaluates the significance of a trend in flow with the effect of precipitation removed
Modeled Flow (cm/mo)
API (cm)
API TREND TEST
Method: Mann−Kendall Trend Test
Period: 1953−2012
p−value: 0.678
Sen Slope: Not Significant
Sen Slope as Percent of
Median Flow: Not Significant
Note: This test evaluates the significance of a trend in precipitation
FLOW VS. API MODEL
Recession Coefficient: 0.99
LOESS Span: 0.9
Spearman's rho: 0.6998
Spearman's rho p−value: 1.123e−11
RMSE: 0.1099
Residual SE: 0.1138

Figure 13. Results of Mann-Kendall 1953–2012 trend tests for flow, flow residual, and API at Scott River near Fort Jones (gage 11519500) for the month of September (left and middle panels). Right panel shows a scatterplot of flow vs. API using the entire period of record (not just 1953–2012), with best-fit LOESS model overlaid. Residual is the error (i.e., observed minus modeled) from the flow vs. API model. Y-axis units for all graphs are centimeters per month (i.e., water volume divided by watershed area)

Table 9. Summary of Mann-Kendall trend tests for 1953-2012 flow with the effect of precipitation accounted for. Cells are shaded by the statistical significance of the trend ($p<0.05$ = dark grey, $0.05<p<0.10$ = light grey, and $p>0.10$ = white). Symbols indicate slope of the trend expressed as a percent of median flow (▲▼ is >±1%, ↑↓ is 0.5-1.0%, and ↾↿ is 0.0-0.5%).

Coho salmon Population	Gage Name and Code	Runoff Type	Hydro Reg.	Trend for Flow with Effects of Precipitation Removed											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chetco	Chetco R (14400000)	R	1	↑	↑	↑	↑	↑	↗	↑	↑	↗	↑	↑	↑
Smith	Smith R (11532500)	R	1	↓	↓	↓	↓	↓	↑	↑	↑	↑	↓	↓	↓
Redwood	Redwood Cr Blue Lake (11481500)	R	1	↓	↓	↑	↑	↓	↑	↓	↘	▼	▼	▼	▼
Redwood	Redwood Cr Orick (11482500)	R	1	↓	↓	↓	↓	↘	↓	↘	↘	↘	▼	▼	↓
Redwood	Redwood Cr Accr: Orick - 299 (c11482500_11481500)	R	1	↓	↓	↓	↓	↓	↓	↓	↘	▼	▼	▼	↘
Little	Little R (11481200)	R	1	↑	↑	↑	↑	↓	↑	↑	↑	↑	↓	↑	↑
Mad	Mad R Arcata (11481000)	R	2	↑	↓	↑	↓	↘	↘	↓	↑	↗	↓	↘	↓
Mattole	Mattole R Petrolia (11469000)	R	1	↓	↓	↑	↓	↘	↓	↓	↓	↘	▼	↘	↓
Lwr Eel/Van Duz	Eel R Scotia (11477000)	R/S	2	↑	↓	↑	↑	↓	↓	↓	↓	↘	↓	↓	↓
Lwr Eel/Van Duz	Van Duzen R (11478500)	R	1	↑	↓	↑	↓	↘	↓	↓	↘	↘	▼	↘	↓
Lwr Eel/Van Duz, Main Eel, SF Eel	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)	R	1	↓	▼	↓	↓	↘	▼	↘	↓	↓	▼	▼	↘
SF Eel	SF Eel R At Leggett (11475800)	R	1	↓	↓	↓	↓	↗	↑	↗	↑	↓	↓	↓	↘
SF Eel	SF Eel R Nr Miranda (11476500)	R	1	↓	↓	↓	↓	↓	↓	↘	↘	↘	↘	↓	↓
SF Eel	Bull Cr (11476600)	R	1	↓	↘	↓	↑	↘	↘	↘	▼	▼	↘	↓	↓
SF Eel	Elder Cr (11475560)	R	1	↑	↗	↑	↗	↗	↑	↑	↑	↑	↗	↑	↑
SF Eel	SF Eel R Accr: Miranda - Leggett (c11476500_11475800)	R	1	↘	↓	↘	↘	↑	↘	▼	▼	▼	↘	▼	↘
Main Eel	Eel R Fort Seward (11475000)	R/S	2	↑	↑	↗	↑	↑	↑	↗	↑	↑	↗	↑	↑
Upr Main Eel	Eel R Van Arsdale (11471500)	R/S	3	↗	↑	↗	↗	▲	▲	▲	▲	▲	▲	▲	▲
Upr Main Eel	Eel R Scott Dam (11470500)	R/S	3	↑	↑	↗	↑	↗	↑	↘	↘	↘	↘	↘	↗
Mid Fork Eel	MF Eel R (11473900)	R/S	1	↓	↑	↑	↗	↑	↘	↓	↓	↓	↗	↑	↑
Mid Main Eel, Main Eel, NF Eel, SF Eel	Eel R Accr: Scotia - Van Ars (c11477000_11471500)	R	1	↑	↓	↑	↑	↓	↘	↓	↘	↘	↘	↓	↓
Mid Main Eel, Main Eel, NF Eel, Mid Fork Eel, SF Eel	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)	R	1	↑	↓	↑	↑	↓	↓	↓	↓	↘	↘	↓	↑
Mid Main Eel, Main Eel, NF Eel	Eel R Accr: Ft Sew - Van Ars - MF (c11475000_11471500_t1)	R	1	↗	↑	↗	↗	↗	↑	↑	▼	▼	↑	↗	↑
Illinois	Illinois R Kerby (14377100)	R/S	1	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑
Illinois	Sucker Cr (14375100)	S	1	↑	↓	↑	↑	↓	↘	↘	↘	↘	↓	↘	↑
Illinois	EF Illinois R (14372500)	R	1	↗	↑	▲	↑	↓	↓	↓	↓	↓	↗	↓	↑
Illinois	Illinois R Accr: Kerby - EF - Sucker Cr (c14377100_14372500_t1)	R/S	1	↑	↑	↑	↑	↑	↑	▲	▼	▲	↑	↑	↑
Mid Rogue/AppleG	Rogue R Grants Pass (14361500)	G	3	↘	▼	↘	↓	↓	↑	↗	▲	↗	↓	↘	↘
Mid Rogue/AppleG	Rogue R Agness (14372300)	G	3	↓	↘	↘	↓	↓	↑	↗	▲	▲	↑	↓	↓
Mid Rogue/AppleG	Rogue R Accr: Agness - Grants Pass (c14372300_14361500_t1)	R/S	1	↓	↘	↓	↓	↓	↗	↗	↑	▲	▲	↗	↑
Mid Rogue/AppleG	Applegate R Copper (14362000)	S	4	↑	▼	▼	▼	↓	↓	▲	▲	▲	▲	↗	↓
Mid Rogue/AppleG	Applegate R Applegate (14366000)	R/S	3	↑	▼	↘	▼	↓	↓	▲	▲	▲	▲	↗	↓
Upr Rogue	Rogue R At Raygold (14359000)	G	3	↘	▼	↘	↘	↓	↑	↗	↗	↗	↓	↘	↘
Upr Rogue	Rogue R Dodge Bridge (14339000)	G	4	↘	▼	↘	↘	↓	↑	↗	↗	↗	↓	↘	↘
Upr Rogue	Rogue R Near Mcleod (14337600)	G	4	↘	▼	▼	↘	↓	↑	↑	↗	↗	↓	↘	↘
Upr Rogue	Rogue R Blw Prospect (14330000)	G	1	↓	↓	↓	↑	↓	↓	↘	↘	↘	↘	↘	↘
Upr Rogue	Rogue R Abv Prospect (14328000)	G	1	↑	↓	↗	↓	↘	↘	↓	↘	↓	↓	↘	↘
Upr Rogue	SF Rogue R Nr Prospect (14332000)	S	1	↗	↘	↑	↑	↓	↘	▲	▲	▲	▲	↗	↓
Upr Rogue	Elk Cr Trail (14338000)	R	1	↓	↘	↓	↓	↘	↘	↘	↘	↘	↘	↘	↘
Upr Rogue	Big Butte Cr Near Mcleod (14337500)	G	2	▼	▼	▼	↘	↘	▼	↘	↘	↓	↓	▼	▼
Upr Rogue	SF Big Butte Cr Ab Willow Cr (14335200)	G	1	↓	↘	↓	↓	↓	↓	↓	↘	↓	↘	↘	↘
Upr Rogue	NF L Butte Cr Nr LakeCr (14343000)	G	4	↓	↓	↓	↓	↘	↘	↘	↓	↑	↑	↓	↓
Upr Rogue	NF L Butte Cr At F L Nr LakeCr (14342500)	S	4	↘	↘	↓	↘	↘	↘	↘	↘	↑	▲	↑	↘
Upr Rogue	Bear Cr At Medford (14357500)	R/S	3	↘	↘	↘	↓	↘	↘	↑	↑	↑	↑	↓	↓
Upr Rogue	Rogue R Accr: Raygold - Mcleod	R/S	2	↘	↘	↘	↓	▼	▼	▼	▼	↘	↓	↘	↘

Coho salmon Population	Gage Name and Code	Runoff Type	Hydro Reg.	Trend for Flow with Effects of Precipitation Removed											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	(c14359000_14337600)														
Upr Rogue	Rogue R Accr: Raygold - Dodge Br (c14359000_14339000)	R	3	↓	↓	↓	↓	▼	▼	▼	▼	↓	↓	↓	↓
Lwr Klamath	Klamath R Klamath (11530500)	S	3	↑	↓	↑	↓	↑	↑	↑	↑	↓	↓	↓	↑
Mid Klamath	Klamath R Orleans (11523000)	S	3	↑	↓	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓
Mid Klamath, Lwr Klamath	Klamath R Accr: Klamath - Orl - TrinityR (c11530500_11523000_t1)	R	1	↑	↓	↑	↑	↓	↑	↑	↓	↓	↑	↑	↑
Mid Klamath	Klamath R Accr: Orl - Sei - SalmR (c11523000_11520500_t2)	S	1	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↓	↑
Mid Klamath	Indian C (11521500)	R/S	1	↑	↑	▲	↑	↑	↑	↑	↑	↑	↓	↓	↑
Upr Klamath	Klamath R Seiad Valley (11520500)	G	3	↓	↓	↓	↓	↓	↓	↓	↓	↓	▼	▼	↓
Upr Klamath	Klamath R Iron Gate Dam (11516530)	G	4	▼	▼	↓	↓	↑	▲	↑	↑	↓	▼	▼	▼
Upr Klamath	Klamath R JCB Pwrplnt (11510700)	G	4	▼	▼	↓	↓	↑	▲	↑	↑	↓	▼	▼	▼
Upr Klamath	Klamath R Keno (11509500)	G	4	▼	▼	↓	↓	↓	↑	↑	↓	▼	▼	▼	▼
Upr Klamath	Link R Klamath Falls (11507500)	S	4	▼	▼	↓	↓	↑	▲	▲	▲	↑	↓	▼	▼
Upr Klamath	Klamath R Accr: Sei - IG - ShastR - ScottR (c11520500_11516530_t1)	S	1	↑	↓	↓	↓	↑	↓	↑	↓	↓	↑	↓	↑
Upr Klamath	Klamath R Accr: Boyle - Keno (c11510700_11509500)	G	2	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑
Upr Klamath	Williamson R Blw Sprague R (11502500)	G	1	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Upr Klamath	Williamson R Klamath Agency (11493500)	S	1	▼	▼	▼	▼	▼	▼	▼	[Median Aug-Oct flow is zero]			▼	▼
Upr Klamath	Williamson R Accr: Bl Sprg - SprgR - K Mrsh (c11502500_11493500_t1)	G	1	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Upr Klamath	Sprague R Chiloquin (11501000)	G	2	↑	↓	↑	↓	↓	↓	↓	▼	↓	↓	↓	↓
Upr Klamath	Sprague R Beatty (11497500)	G	2	↓	↓	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓
Upr Klamath	Sprague R Accr: Chiloquin - Beatty (c11501000_11497500)	G	1	↑	↓	↓	↓	↓	↓	▼	▼	▼	↓	↓	↓
Upr Klamath	Sprague R: Williamson R - Sprague (c11502500_11501000)	G	1	↓	▼	▼	▼	▼	↓	↓	↓	↓	↓	↓	▼
Salmon	Salmon R (11522500)	S	1	▲	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Scott	Scott R Ft Jones (11519500)	S	1	↑	↓	↑	↓	↓	↓	↓	▼	▼	▼	↓	↓
Shasta	Shasta R Yreka (11517500)	G	3	↓	↓	↑	↑	↑	↑	▲	↑	↓	↓	↓	↓
Lwr Trinity	Trinity R Hoopa (11530000)	R/S	4	↑	↓	↑	↓	↑	↓	↑	↑	▲	↑	↓	↓
Lwr Trinity	Trinity R Burnt Ranch (11527000)	S	4	↑	↓	↑	↓	▲	↑	▲	▲	▲	↑	↑	↓
Lwr Trinity	Trinity R Accr: Hoopa - Burnt Ranch - SF (c11530000_11527000_t1)	R/S	1	↑	↓	↑	↑	↑	↑	↑	↑	↑	↑	↓	↓
Upr Trinity	Trinity R Lewiston (11525500)	S	4	↓	▼	▼	▼	▲	↓	▲	▲	▲	▲	↑	▼
Upr Trinity	Trinity R Coffee Cr (11523200)	S	1	↑	↓	↑	↑	↓	↑	↑	↑	↓	↓	↑	↓
Upr Trinity, Lwr Trinity	Trinity R Accr: Burnt Ranch - Lewiston (c11527000_11525500)	S	1	↑	↓	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓
Upr Trinity, Lwr Trinity	Trinity R Accr: Hoopa - Lewiston (c11530000_11525500)	R/S	1	↑	↑	↑	↑	↑	↓	↑	↓	↓	↓	↓	↑
SF Trinity	SF Trinity Hyampom (11528700)	R/S	1	↑	↑	↑	↑	↑	↑	↑	↑	↓	↑	↑	▲
% of hydrologic regulation rating 1 sites with **decreasing** trend (p< 0.10)				**16**	**23**	**11**	**14**	**20**	**30**	**36**	**48**	**50**	**43**	**48**	**32**
% of hydrologic regulation rating 1 sites with **increasing** trend (p< 0.10)				**16**	**0**	**27**	**5**	**0**	**0**	**11**	**11**	**9**	**9**	**7**	**7**
% of hydrologic regulation rating 2,3, or 4 sites with **decreasing** trend (p<0.10)				**41**	**62**	**38**	**38**	**28**	**19**	**22**	**31**	**34**	**47**	**56**	**50**
% of hydrologic regulation rating 2,3, or 4 sites with **increasing** trend (p<0.10)				**9**	**3**	**25**	**3**	**16**	**19**	**47**	**38**	**41**	**31**	**12**	**12**

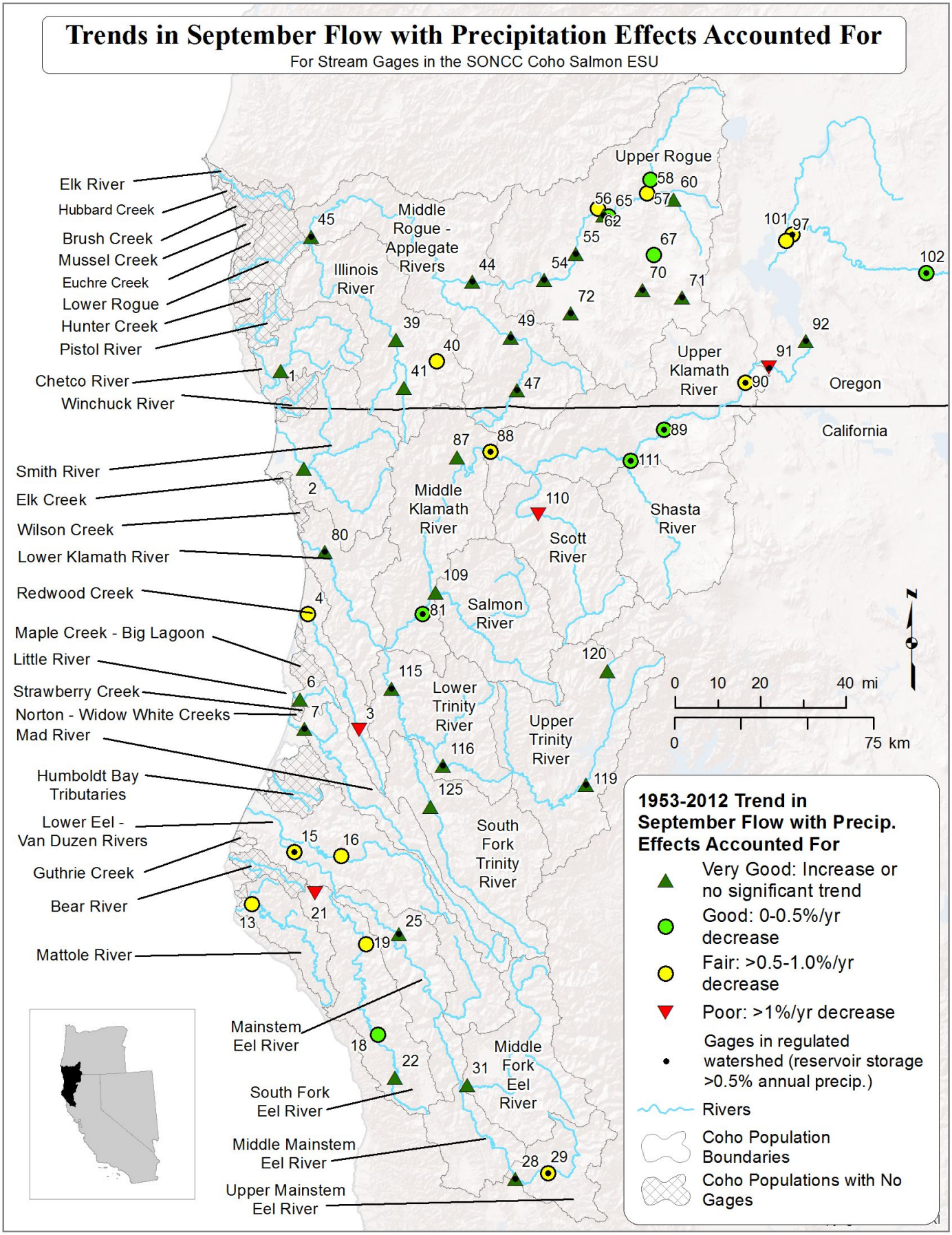

Figure 14. Map of 1953-2012 trends for September streamflow with the effects of precipitation accounted for. Gages are color-coded according to the rules in Table 2.

Table 10. Aug–Nov 1953-2012 trend slopes for flow and flow with effect of precipitation accounted for. Only includes sites with hydrologic regulation rating 1 (res. vol. <0.5% of precip.) and site-months with significant ($p<0.10$) trends. Orange: -, Blue: +

Coho salmon Population	Gage Name and Code	Runoff Type	Slope of Flow Trend (%/yr)				Slope of Flow Trend with Precip. Accounted for (%/yr)				% of Flow Trend Not Due to Precipitation			
			Aug	Sep	Oct	Nov	Aug	Sep	Oct	Nov	Aug	Sep	Oct	Nov
Chetco	Chetco R (14400000)	R						0.6						
Smith	Smith R (11532500)	R					0.2			-0.5				
Redwood	Redwood Cr Blue Lake (11481500)	R	-0.8	-1.8	-2.0		-0.9	-1.1	-2.8	-3.1	111	60	138	
Redwood	Redwood Cr Orick (11482500)	R	-0.8	-1.7	-1.5	-1.6	-0.9	-1.0	-1.4	-1.0	114	57	93	62
Redwood	Redwood Cr Accr: Orick - 299 (c11482500_11481500)	R		-2.2	-2.3	-1.8	-0.8	-1.2	-1.0	-1.4		53	45	77
Mattole	Mattole R Petrolia (11469000)	R	-0.6	-1.3		-1.4	-0.5	-0.6	-1.0	-0.6	78	48		45
Lwr Eel/Van Duz	Van Duzen R (11478500)	R	-1.0	-1.3			-0.7	-0.7	-1.1	-0.8	75	56		
Lwr Eel/Van Duz, Main Eel, SF Eel	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)	R		-1.2	-1.3	-1.8			-1.5	-1.1			114	60
SF Eel	SF Eel R At Leggett (11475800)	R		-1.2				-0.4				33		
SF Eel	SF Eel R Nr Miranda (11476500)	R	-1.0	-1.2		-1.1	-0.8	-0.8	-0.6	-0.5	76	63		43
SF Eel	Bull Cr (11476600)	R	-1.7	-2.7	-1.4	-3.4	-1.4	-1.9	-0.8		80	69	57	
SF Eel	Elder Cr (11475560)	R		-1.1										
SF Eel	SF Eel R Accr: Miranda - Leggett (c11476500_11475800)	R	-1.9	-2.0			-1.4	-1.0		-1.6	73	50		
Mid Fork Eel	MF Eel R (11473900)	R/S		-1.5										
Mid Main Eel, Main Eel, NF Eel, SF Eel	Eel R Accr: Scotia - Van Ars (c11477000_11471500)	R	-0.8	-1.4		-1.4	-0.5	-0.9	-0.5		64	65		
Mid Main Eel, Main Eel, NF Eel, Mid Fork Eel, SF Eel	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)	R	-0.7	-1.4				-0.7				46		
Mid Main Eel, Main Eel, NF Eel	Eel R Accr: Ft Sew - Van Ars - MF (c11475000_11471500_t1)	R	-2.5	-4.8			-1.8	-2.8			71	58		
Illinois	Illinois R Kerby (14377100)	R/S		-0.7										
Illinois	Sucker Cr (14375100)	S		-0.7			-0.5	-0.6		-0.7		85		
Illinois	EF Illinois R (14372500)	R	-0.5	-0.5					0.6					
Illinois	Illinois R Accr: Kerby - EF - Sucker Cr (c14377100_14372500_t1)	R/S	-5.7				-5.8				102			
Mid Rogue/AppleG	Rogue R Accr: Agness - Grants Pass (c14372300_14361500_t1)	R/S							1.2	0.6				
Upr Rogue	Rogue R Blw Prospect (14330000)	G	-0.6	-0.6	-0.5	-0.6	-0.9	-0.9	-0.7	-0.8	167	152	146	121
Upr Rogue	Rogue R Abv Prospect (14328000)	G		-0.4	-0.5		-0.5	-0.4	-0.5	-0.9		105	85	
Upr Rogue	SF Rogue R Nr Prospect (14332000)	S	5.0	3.3	5.9	1.4	5.0	4.4	5.8	1.0	98	134	100	72
Upr Rogue	Elk Cr Trail (14338000)	R		-0.9			-0.7	-0.7	-0.8	-1.0		77		
Upr Rogue	SF Big Butte Cr Ab Willow Cr (14335200)	G			-0.6	-0.5	-0.5	-0.4	-0.6	-0.6			97	117
Mid Klamath	Klamath R Accr: Orl - Sei - SalmR (c11523000_11520500_t2)	S					0.4	0.6						
Mid Klamath	Indian C (11521500)	R/S		-0.4										
Upr Klamath	Klamath R Accr: Sei - IG - ShastR - ScottR (c11520500_11516530_t1)	S				-1.8				-0.8				46
Upr Klamath	Williamson R Blw Sprague R (11502500)	G	-0.7	-0.6	-0.6	-0.8	-0.7	-0.6	-0.6	-0.8	97	95	99	97
Upr Klamath	Williamson R Klamath Agency (11493500)	S				-4.1				-4.1				101
Upr Klamath	Williamson R Accr: Bl Sprg - SprgR - K Mrsh (c11502500_11493500_t1)	G		-0.2	-0.3	-0.2			-0.2	-0.2			78	68
Upr Klamath	Sprague R Accr: Chiloquin - Beatty (c11501000_11497500)	G	-2.2	-1.6	-1.1	-0.8	-2.1	-1.5	-0.9	-0.6	91	92	89	81
Upr Klamath	Sprague R: Williamson R - Sprague (c11502500_11501000)	G	-0.2	-0.2	-0.4	-0.9	-0.2	-0.3	-0.5	-1.0	100	114	110	107
Salmon	Salmon R (11522500)	S					0.4	0.3	0.3	0.6				
Scott	Scott R Ft Jones (11519500)	S	-2.1	-1.9	-1.2	-1.3	-1.8	-1.7	-1.3	-0.7	85	88	114	56
Upr Trinity, Lwr Trinity	Trinity R Accr: Burnt Ranch - Lewiston (c11527000_11525500)	S					-0.7							
SF Trinity	SF Trinity Hyampom (11528700)	R/S		-0.9										

3.2 COMPARISON OF HUMAN WATER USES AND STREAMFLOW

A comparison of human water uses and streamflow is provided in Table 11 and illustrated in Figure 15. Agricultural water use was much higher than 7-day minimum streamflow in some watersheds with large-scale irrigation (Shasta River, Scott River). Indoor/outdoor residential water use was only a small fraction of 7-day minimum streamflow in most streams, exceptions for urbanized areas, such as the Medford and Ashland (Upper Rogue coho salmon population), Yreka (Shasta River coho salmon population), and Willits (Middle Mainstem Eel River coho salmon population).

As a supplemental analysis (i.e., used for understanding patterns at an ESU-wide scale but not used in the development of the stress and threat ranks for any specific coho salmon population), I assessed the relationship between human water use and long-term trends in streamflow. Human water use appears to have an effect on the frequency of significant increasing or decreasing trends in flow (with the effect of precipitation accounted for; Table 12), although statistical tests were not conducted to support this conclusion. Gages in regulated and unregulated streams are displayed separately in Table 12 because, as shown in Table 9 and discussed above in Section 3.1, regulated streams were less likely to have significant declining trends in summer flow (with the effect of precipitation accounted for). The percentage of gages with significant long-term declining flow (with the effects of precipitation accounted for) trends was lower in streams where human water use was less than 2% of median month flow (i.e., those with extremely low human population density and little or no agriculture) than gages in streams where human water use was greater than 2% of median monthly flow (Table 12). For example, for the month of September at unregulated gages, only 33% of gages with <2% water use had declining streamflow trends, whereas 50-55% of gages with ≥2% water use had declining trends. Water use had an even stronger effect on the frequency of increasing trends (Table 12).

Table 11. Human water use estimates (Ag. = agriculture ETAW, Dom. Out = domestic outdoor, Dom. Ind. = domestic indoor) and comparison with median (from partial or complete 1981-2010 flow data) 7-day and 30-day minimum flow. Key to hydrologic regulation ratings (reservoir volume): 1= reservoir storage volume is 0-0.5% of precipitation, 2 = 0.5-5%, 3 = 5-15%, 4 = >15%. Total water use is color coded according to rules in Table 3 (>50% = poor, 20-50 = fair, 2-20 = good, <2 = very good).

Map Label	Coho Population	Gage Name and Code	Run. Type	Reservoir Volume		streamflow (cfs)		Water use (cfs)				Water use (as % of 30-day low flow)			
				% of precip	Rat-ing	30d low flow	7d low flow	Ag.	Dom. Out.	Dom. Ind.	Tot. Use	Ag.	Dom. Out.	Dom. Ind.	Tot Use.
1	Chetco	Chetco R (14400000)	R	0.0	1	75.9	69.9	0.2	0.0	0.0	0.2	0.3	0.0	0.0	0.3
2	Smith	Smith R (11532500)	R	0.0	1	251.9	233.4	0.1	0.3	0.1	0.5	0.0	0.1	0.0	0.2
3	Redwood	Redwood Cr Blue Lake (11481500)	R	0.0	1	3.7	3.2	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.8
4	Redwood	Redwood Cr Orick (11482500)	R	0.0	1	14.0	11.1	0.2	0.1	0.0	0.3	1.4	0.7	0.2	2.3
5	Redwood	Redwood Cr Accr: Orick - 299 (c11482500_11481500)	R	0.0	1	10.7		0.2	0.1	0.0	0.3	1.8	0.7	0.2	2.8
6	Little	Little R (11481200)	R	0.0	1	5.0	4.2	0.1	0.0	0.0	0.1	2.1	0.6	0.2	2.9
7	Mad	Mad R Arcata (11481000)	R	3.2	2	35.8	31.1	2.0	1.7	0.5	4.3	5.6	4.8	1.5	11.9
8	Mad	Mad R Forest Glen (11480500)	R	13.4	3	38.1	24.4	0.0	0.1	0.0	0.2	0.0	0.4	0.1	0.5
9	Mad	Mad R Bl Ruth Res (11480410)	R	13.4	3	43.0	40.4	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.2
10	Mad	Mad R Ab Ruth Res (11480390)	R	0.0	1	0.0	0.0	0.0	0.1	0.0	0.1				
11	Mad	Mad R Accr: Arcata - Bl Ruth Res (c11481000_11480410)	R	0.0	1	-30.6		2.0	1.7	0.5	4.2	-6.6	-5.4	-1.6	-13.6
12	Mattole	Mattole R Ettersburg (11468900)	R	0.0	1	6.5	5.8	0.0	0.2	0.1	0.3	0.0	3.0	0.9	3.9
13	Mattole	Mattole R Petrolia (11469000)	R	0.0	1	27.4	24.6	1.8	0.4	0.1	2.3	6.4	1.6	0.5	8.5
14	Mattole	Mattole R Accr: Petrolia - Ettersburg (c11469000_11468900)	R	0.0	1	16.1		1.8	0.2	0.1	2.1	10.9	1.5	0.5	12.9
15	Lwr Eel/Van Duz	Eel R Scotia (11477000)	R/S	0.9	2	86.8	77.6	32.0	9.6	2.9	44.5	36.9	11.1	3.3	51.3
16	Lwr Eel/Van Duz	Van Duzen R (11478500)	R	0.0	1	7.6	7.0	0.0	0.3	0.1	0.4	0.0	3.7	1.1	4.8
17	Lwr Eel/Van Duz, Main Eel, SF Eel	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)	R	0.0	1	17.1		2.0	1.4	0.4	3.8	11.8	8.2	2.5	22.5
18	SF Eel	SF Eel R At Leggett (11475800)	R	0.0	1	16.7	15.6	1.1	1.0	0.3	2.4	6.7	6.0	1.8	14.5
19	SF Eel	SF Eel R Nr Miranda (11476500)	R	0.1	1	30.8	28.0	1.1	2.4	0.7	4.3	3.6	7.9	2.4	14.0
21	SF Eel	Bull Cr (11476600)	R	0.0	1	1.0	0.8	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.4
22	SF Eel	Elder Cr (11475560)	R	0.0	1	0.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
23	SF Eel	SF Eel R Accr: Miranda - Leggett (c11476500_11475800)	R	0.1	1	12.9		0.0	1.5	0.4	1.9	0.0	11.2	3.4	14.6
25	Main Eel	Eel R Fort Seward (11475000)	R/S	1.3	2	28.0	23.1	28.9	5.8	1.7	36.4	103.3	20.6	6.2	130.0
26	Mid Main Eel	Eel R Dos Rios (11472150)	R/S	6.8	3	9.5	8.0	0.0	0.2	0.1	0.3	0.0	2.3	0.7	3.0
27	Mid Main Eel	Outlet Cr (11472200)	R	0.8	2	0.4	0.2	28.9	4.3	1.3	34.5	7413	1104	333.6	8850.8
28	Upr Main Eel	Eel R Van Arsdale (11471500)	R/S	8.4	3	7.5	6.9	0.0	0.0	0.0	0.1	0.0	0.6	0.2	0.8
29	Upr Main Eel	Eel R Scott Dam (11470500)	R/S	10.1	3	106.5	85.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	NF Eel	NF Eel R (11474500)	R	0.0	1	0.4	0.3	0.0	0.0	0.0	0.1	0.0	12.2	3.7	15.8
31	Mid Fork Eel	MF Eel R (11473900)	R/S	0.1	1	10.4	8.7	0.0	0.9	0.3	1.1	0.0	8.3	2.5	10.8
32	Mid Fork Eel	Black Butte R (11472900)	S	0.0	1	3.3	2.9	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.5
33	Mid Main Eel, Main Eel, NF Eel, SF Eel	Eel R Accr: Scotia - Van Ars (c11477000_11471500)	R	0.1	1	74.1		32.0	9.6	2.9	44.5	43.2	12.9	3.9	60.0
34	Mid Main Eel, Main Eel, NF Eel, Mid Fork Eel, SF Eel	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)	R	0.1	1	35.1		30.9	7.1	2.1	40.2	88.0	20.2	6.1	114.4
35	Mid Main Eel, Main Eel, NF Eel	Eel R Accr: Ft Sew - Van Ars - MF (c11475000_11471500_t1)	R	0.1	1	2.9		28.9	4.8	1.5	35.2	985.1	165.0	49.9	1200.0
36	Main Eel, NF Eel	Eel R Accr: Ft Sew - DRios - MF - Outl (c11475000_11472150_t1)	R	0.0	1	3.7		0.0	0.4	0.1	0.5	0.0	9.9	3.0	12.9

Map Label	Coho Population	Gage Name and Code	Run. Type	Reservoir Volume		streamflow (cfs)		Water use (cfs)				Water use (as % of 30-day low flow)			
				% of precip	Rat-ing	30d low flow	7d low flow	Ag.	Dom. Out.	Dom. Ind.	Tot. Use	Ag.	Dom. Out.	Dom. Ind.	Tot Use.
37	Mid Main Eel, Main Eel	Eel R Accr: Dos Rios - Van Ars (c11472150_11471500)	R	0.0	1	-1.8		0.0	0.2	0.1	0.2	0.0	-9.7	-2.9	-12.7
39	Illinois	Illinois R Kerby (14377100)	R/S	0.0	1	33.7	29.8	17.2	2.7	0.8	20.7	51.1	8.0	2.4	61.5
40	Illinois	Sucker Cr (14375100)	S	0.0	1	23.4	21.7	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
41	Illinois	EF Illinois R (14372500)	R	0.0	1	8.7	7.9	0.1	0.1	0.0	0.3	1.5	1.1	0.3	2.9
42	Illinois	WF Illinois R (14375500)	R	0.0	1	6.3	5.8	0.0	0.0	0.0	0.1	0.7	0.8	0.2	1.7
43	Illinois	Illinois R Accr: Kerby - EF - Sucker Cr (c14377100_14372500_t1)	R/S	0.0	1	-9.6		17.1	2.6	0.8	20.4	-178.5	-26.8	-8.1	-213.5
44	Mid Rogue/AppleG	Rogue R Grants Pass (14361500)	G	11.5	3	1328	1207	373.9	73.0	22.1	469.0	28.2	5.5	1.7	35.3
45	Mid Rogue/AppleG	Rogue R Agness (14372300)	G	7.8	3	1684	1491	451.0	96.1	29.0	576.0	26.8	5.7	1.7	34.2
46	Mid Rogue/AppleG	Rogue R Accr: Agness - Grants Pass (c14372300_14361500_t1)	R/S	0.1	1	-15.3		66.5	22.0	6.6	95.1	-436.0	-143.8	-43.5	-623.2
47	Mid Rogue/AppleG	Applegate R Copper (14362000)	S	15.7	4	136.5	116.5	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
48	Mid Rogue/AppleG	Applegate R Wilderville (14369500)	R/S	6.3	3	217.4	189.2	49.8	3.9	1.2	54.8	22.9	1.8	0.5	25.2
49	Mid Rogue/AppleG	Applegate R Applegate (14366000)	R/S	8.9	3	168.3	161.6	10.5	1.1	0.3	11.9	6.2	0.7	0.2	7.1
50	Mid Rogue/AppleG	Applegate R Accr: Wilderville - Applgt (c14369500_14366000)	R	0.1	1	-27.0		39.3	2.8	0.8	42.9	-145.5	-10.2	-3.1	-158.7
51	Mid Rogue/AppleG	Applegate R Accr: Applgt - Copper (c14366000_14362000)	R/S	0.0	1	-29.6		10.4	1.1	0.3	11.9	-35.2	-3.7	-1.1	-40.0
52	Mid Rogue/AppleG	Grave Cr (14371500)	R	0.0	1	1.1	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.7
53	Mid Rogue/AppleG	Star Gulch (14362250)	R	0.0	1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	6.8	2.0	8.8
54	Upr Rogue	Rogue R At Raygold (14359000)	G	13.4	3	1287	1204	335.2	63.8	19.3	418.3	26.1	5.0	1.5	32.5
55	Upr Rogue	Rogue R Dodge Bridge (14339000)	G	16.6	4	1148	1113	18.3	2.9	0.9	22.1	1.6	0.3	0.1	1.9
56	Upr Rogue	Rogue R Near Mcleod (14337600)	G	20.8	4	1031.3	950.3	3.1	0.8	0.2	4.1	0.3	0.1	0.0	0.4
57	Upr Rogue	Rogue R Blw Prospect (14330000)	G	0.1	1	803.2	787.5	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0
58	Upr Rogue	Rogue R Abv Prospect (14328000)	G	0.0	1	412.7	387.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
59	Upr Rogue	SF Rogue R S Prospect (14334700)	G	0.1	1	106.5	102.9	1.2	0.0	0.0	1.3	1.2	0.0	0.0	1.2
60	Upr Rogue	SF Rogue R Nr Prospect (14332000)	S	0.0	1	11.2	10.6	0.1	0.0	0.0	0.1	0.5	0.0	0.0	0.5
62	Upr Rogue	Elk Cr Trail (14338000)	R	0.0	1	3.9	2.9	0.3	0.0	0.0	0.4	7.9	1.2	0.4	9.5
63	Upr Rogue	Elk Cr Cascade Gorge (14337800)	R	0.0	1	3.8	3.2	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.7
64	Upr Rogue	WB Elk Cr Trail (14337870)	R	0.0	1	0.9	0.8	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.6
65	Upr Rogue	Big Butte Cr Near Mcleod (14337500)	G	2.4	2	55.7	50.7	1.3	0.4	0.1	1.8	2.3	0.7	0.2	3.2
66	Upr Rogue	SF Big Butte Cr Nr Butte Falls (14335500)	G	4.3	2	54.0	50.8	0.8	0.0	0.0	0.9	1.5	0.1	0.0	1.6
67	Upr Rogue	SF Big Butte Cr Ab Willow Cr (14335200)	G	0.0	1	37.4	36.1	0.8	0.0	0.0	0.8	2.2	0.0	0.0	2.2
68	Upr Rogue	Little Butte Cr At LakeCr (14346700)	S	6.8	3	22.3	18.8	6.7	0.1	0.0	6.8	30.1	0.4	0.1	30.6
69	Upr Rogue	SF Little Butte Cr Nr LakeCr (14341500)	S	0.0	1	10.2	8.5	0.7	0.0	0.0	0.7	6.5	0.4	0.1	7.1
70	Upr Rogue	NF L Butte Cr Nr LakeCr (14343000)	G	24.5	4	38.8	30.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	Upr Rogue	NF L Butte Cr At F L Nr LakeCr (14342500)	S	50.7	4	5.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
72	Upr Rogue	Bear Cr At Medford (14357500)	R/S	12.0	3	30.2	21.9	75.1	22.1	6.7	103.8	248.6	73.1	22.1	343.8
73	Upr Rogue	Bear Cr Blw Ashland Cr (14354200)	R/S	18.8	4	16.3	13.0	21.4	7.8	2.3	31.6	131.3	47.6	14.4	193.3
74	Upr Rogue	WF Ashland Cr Near Ashland (14353000)	S	0.0	1	2.4	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75	Upr Rogue	EF Ashland Cr Near Ashland (14353500)	S	0.0	1	2.6	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
76	Upr Rogue	Emigrant Cr Nr Ashland (14350000)	R	44.1	4	0.3	0.3	0.8	0.2	0.1	1.0	252.0	74.0	22.4	348.3
77	Upr Rogue	NF L Butte Cr Accr: Nr Lake Cr - Falls (c14343000_14342500)	G	0.0	1	19.3		0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
78	Upr Rogue	Rogue R Accr: Raygold - Mcleod (c14359000_14337600)	R/S	4.8	2	-4.6		332.1	63.1	19.1	414.2	-7227	-1372	-414.8	-9014.3
79	Upr Rogue	Rogue R Accr: Raygold - Dodge Br (c14359000_14339000)	R	7.0	3	-18.0		316.8	60.9	18.4	396.2	-1763	-339.0	-102.5	-2204.2
80	Lwr Klamath	Klamath R Klamath (11530500)	S	15.0	3	2771	2589	2278	41.2	12.4	2332	82.2	1.5	0.5	84.1
81	Mid Klamath	Klamath R Orleans (11523000)	S	10.5	3	1715	1679	2264	34.6	10.5	2309	132.0	2.0	0.6	134.7
85	Mid Klamath, Lwr	Klamath R Accr: Klamath - Orl - TrinityR	R	0.0	1	445.9		10.5	1.0	0.3	11.8	2.4	0.2	0.1	2.7

Map Label	Coho Population	Gage Name and Code	Run. Type	Reservoir Volume		streamflow (cfs)		Water use (cfs)				Water use (as % of 30-day low flow)			
				% of precip	Rat-ing	30d low flow	7d low flow	Ag.	Dom. Out.	Dom. Ind.	Tot. Use	Ag.	Dom. Out.	Dom. Ind.	Tot Use.
	Klamath	(c11530500_11523000_t1)													
86	Mid Klamath	Klamath R Accr: Orl - Sei - SalmR (c11523000_11520500_t2)	S	0.0	1	258.7		0.5	0.6	0.2	1.2	0.2	0.2	0.1	0.5
87	Mid Klamath	Indian C (11521500)	R/S	0.0	1	41.8	39.5	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.3
88	Upr Klamath	Klamath R Seiad Valley (11520500)	G	14.4	3	1111	1041	2263	33.9	10.3	2307	203.8	3.1	0.9	207.8
89	Upr Klamath	Klamath R Iron Gate Dam (11516530)	G	18.9	4	768.7	728.9	1739.8	23.9	7.2	1770.9	226.3	3.1	0.9	230.4
90	Upr Klamath	Klamath R JCB Pwrplnt (11510700)	G	19.2	4	638.2	520.6	1557.0	23.1	7.0	1587.0	244.0	3.6	1.1	248.7
91	Upr Klamath	Klamath R Keno (11509500)	G	19.8	4	394.8	317.6	1550.9	22.9	6.9	1580.7	392.8	5.8	1.8	400.4
92	Upr Klamath	Link R Klamath Falls (11507500)	S	17.7	4	467.3	295.7	379.4	7.2	2.2	388.8	81.2	1.5	0.5	83.2
93	Upr Klamath	Klamath R Accr: Sei - IG - ShastR - ScottR (c11520500_11516530_t1)	S	0.0	1	66.6		21.4	0.8	0.3	22.6	32.2	1.3	0.4	33.9
95	Upr Klamath	Klamath R Accr: Boyle - Keno (c11510700_11509500)	G	1.4	2	195.1		6.0	0.2	0.1	6.3	3.1	0.1	0.0	3.2
97	Upr Klamath	Williamson R Blw Sprague R (11502500)	G	0.3	1	441.1	428.9	119.5	1.3	0.4	121.2	27.1	0.3	0.1	27.5
98	Upr Klamath	Williamson R Klamath Agency (11493500)	S	0.0	1	0.0	0.0	30.2	0.1	0.0	30.4				
99	Upr Klamath	Williamson R Sheep Cr (11491400)	G	0.0	1	44.5	43.2	0.4	0.0	0.0	0.4	0.8	0.0	0.0	0.8
100	Upr Klamath	Williamson R Accr: Bl Sprg - SprgR - K Mrsh (c11502500_11493500_t1)	G	0.0	1	229.3		2.6	0.5	0.1	3.2	1.1	0.2	0.1	1.4
101	Upr Klamath	Sprague R Chiloquin (11501000)	G	0.6	2	142.2	119.6	86.6	0.7	0.2	87.6	60.9	0.5	0.2	61.6
102	Upr Klamath	Sprague R Beatty (11497500)	G	1.4	2	89.0	84.1	18.5	0.2	0.1	18.8	20.8	0.2	0.1	21.1
103	Upr Klamath	NF Sprague R Power Plant (11495800)	G	0.0	1	27.9	26.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
104	Upr Klamath	Sycan R Snake Cr (11499100)	G	0.0	1	15.3	12.5	7.6	0.0	0.0	7.7	50.0	0.2	0.0	50.2
105	Upr Klamath	Sprague R Accr: Chiloquin - Beatty (c11501000_11497500)	G	0.2	1	46.4		68.1	0.5	0.2	68.9	146.8	1.2	0.4	148.3
106	Upr Klamath	Sprague R: Williamson R - Sprague (c11502500_11501000)	G	0.0	1	262.5		32.8	0.6	0.2	33.6	12.5	0.2	0.1	12.8
107	Upr Klamath	Annie Spring (11503000)	G	0.0	1	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
109	Salmon	Salmon R (11522500)	S	0.0	1	170.4	155.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1
110	Scott	Scott R Ft Jones (11519500)	S	0.1	1	17.5	16.3	185.1	1.8	0.5	187.4	1055	10.1	3.1	1068.6
111	Shasta	Shasta R Yreka (11517500)	G	5.6	3	25.7	19.0	316.9	7.4	2.2	326.6	1232	28.8	8.7	1269.3
112	Shasta	Shasta R Montague (11517000)	G	6.3	3	28.5	24.7	240.6	3.5	1.0	245.1	843.2	12.1	3.7	859.0
114	Shasta	Shasta R Accr: Yreka - Montague (c11517500_11517000)	G	0.5	1	-8.0		76.4	3.9	1.2	81.5	-956.0	-49.3	-14.9	-1020.3
115	Lwr Trinity	Trinity R Hoopa (11530000)	R/S	30.4	4	690.6	626.1	3.9	5.5	1.7	11.0	0.6	0.8	0.2	1.6
116	Lwr Trinity	Trinity R Burnt Ranch (11527000)	S	62.6	4	467.7	429.0	0.0	2.9	0.9	3.8	0.0	0.6	0.2	0.8
117	Lwr Trinity	Trinity R Accr: Hoopa - Burnt Ranch - SF (c11530000_11527000_t1)	R/S	0.0	1	124.0		0.0	1.5	0.5	2.0	0.0	1.2	0.4	1.6
118	Upr Trinity	Trinity R Limekiln Glch (11525655)	S	104.6	4	321.3	300.9	0.0	0.9	0.3	1.1	0.0	0.3	0.1	0.4
119	Upr Trinity	Trinity R Lewiston (11525500)	S	115.0	4	291.7	283.4	0.0	0.3	0.1	0.4	0.0	0.1	0.0	0.1
120	Upr Trinity	Trinity R Coffee Cr (11523200)	S	0.0	1	35.1	32.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
122	Upr Trinity	Grass Valley Cr Fawn Lodge (11525600)	R	1.4	2	10.1	9.6	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.4
123	Upr Trinity, Lwr Trinity	Trinity R Accr: Burnt Ranch - Lewiston (c11527000_11525500)	S	0.1	1	68.2		0.0	2.6	0.8	3.4	0.0	3.8	1.2	5.0
124	Upr Trinity, Lwr Trinity	Trinity R Accr: Hoopa - Lewiston (c11530000_11525500)	R/S	0.0	1	283.5		3.9	5.2	1.6	10.6	1.4	1.8	0.6	3.8
125	SF Trinity	SF Trinity Hyampom (11528700)	R/S	0.0	1	57.1	53.5	3.9	1.1	0.3	5.3	6.8	1.9	0.6	9.2

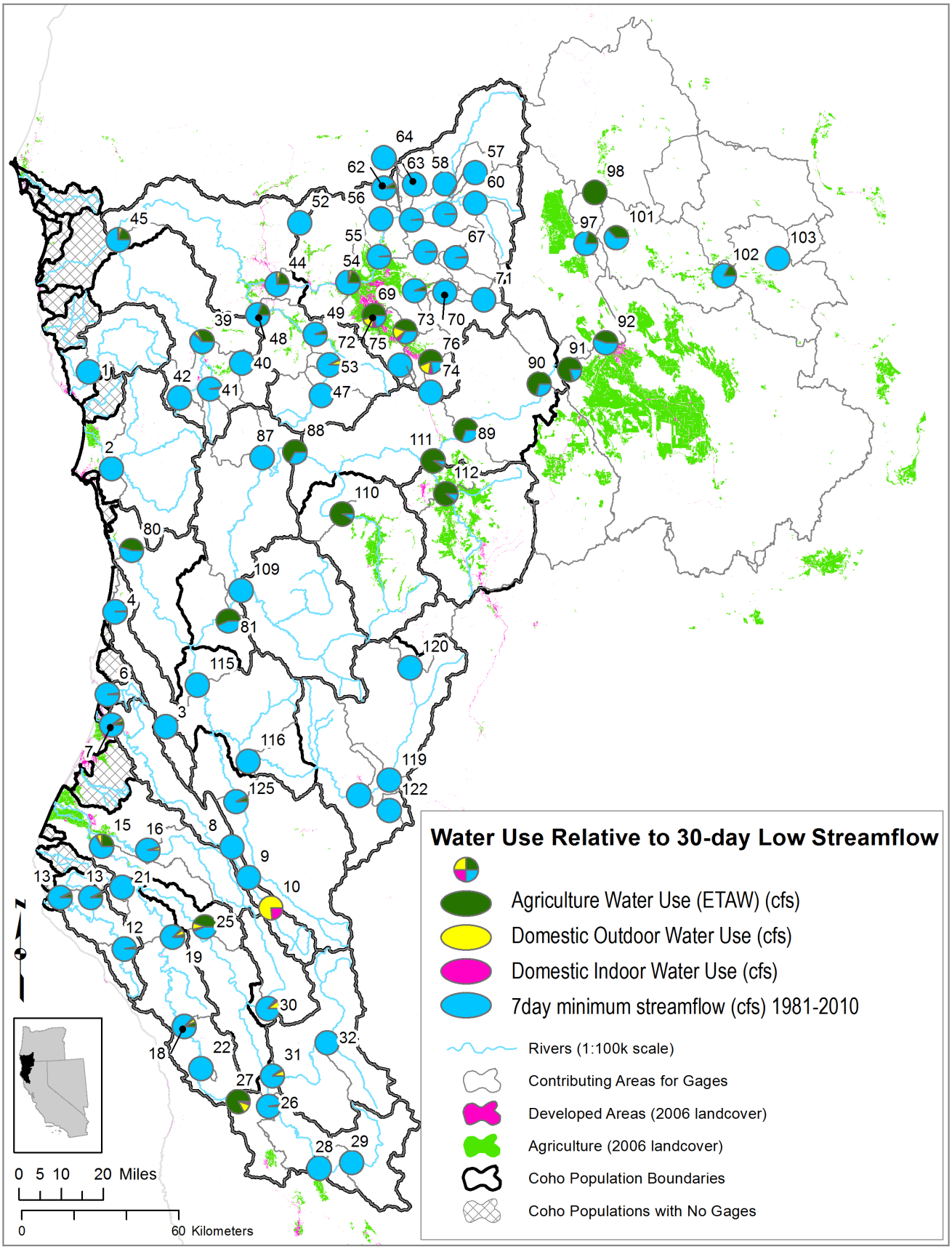
Water Use Relative to 30-day Low Streamflow
Agriculture Water Use (ETAW) (cfs)
Domestic Outdoor Water Use (cfs)
Domestic Indoor Water Use (cfs)
7day minimum streamflow (cfs) 1981-2010
Rivers (1:100k scale)
Contributing Areas for Gages
Developed Areas (2006 landcover)
Agriculture (2006 landcover)
Coho Population Boundaries
Coho Populations with No Gages
N
0 5 10 20 Miles
0 60 Kilometers

Figure 15. Map comparing human water use and 30-day minimum flow for stream gages within the SONCC coho ESU. Pie chart placed at each gage location compares minimum 30-day average streamflow (at the gage, based on the median value for 1981-2010) and instantaneous rates of summer water use in the contributing watershed. Whole pie = agricultural water use + domestic indoor water use + domestic outdoor water use + 30d min flow. Numeric labels refer to locations in Table 4.

Table 12. Effect of hydrologic regulation and human water use on the frequency of significant trends in flow with precipitation effects accounted for.

Stream Type*	Human Water Use as % of Monthly Median Flow	% of Sites With Significant **Decreasing** Trend in Flow With Precipitation Effects Accounted For						% of Sites With Significant **Increasing** Trend in Flow With Precipitation Effects Accounted For					
		May	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Unregulated	<2	35	16	25	22	33	35	12	0	0	19	29	30
	2-20	44	0	40	33	55	58	11	0	0	11	9	0
	>20	46	30	27	58	50	50	0	0	0	8	0	0
Regulated	<2	36	36	27	30	30	10	64	21	18	70	70	70
	2-20	56	27	17	25	28	44	6	9	25	38	22	17
	>20	25	12	10	14	40	40	50	12	10	29	20	60

*Unregulated streams are defined as having no reservoirs or where the total storage of all reservoirs present is less than 0.5% of the annual precipitation in the watershed. A regulated stream is defined where reservoir storage is greater than 0.5% of annual precipitation for that watershed.

3.3 RESERVOIR STORAGE AND FISH PASSAGE AT DAMS

Reservoir volume as a percent of annual precipitation is shown in Table 13 for each coho salmon population. Only precipitation and reservoirs that occur within the population boundary (not areas upstream) were included, so for some populations in the large river basins (Rogue, Klamath, Trinity, and Eel) there are reservoirs and precipitation upstream of the population boundary that affect flow within the population but are not included in the population-level statistics. For statistics that include the upstream precipitation and reservoirs, refer to the stream gage data (Table 11, Figure 16). Table 13 also lists the percent of coho salmon habitat in each population that is inaccessible due to dams.

3.4 OTHER WATERSHED INDICATORS OF HYDROLOGIC FUNCTION

Table 13 shows values and ratings for GIS-based watershed indicators of hydrologic function: agriculture, impervious area, road density, and human population density. Definitions of ranks for human population density are based on approximate quartiles (i.e. percentiles: 0-25%, 25-50%, 50-75%, and 75-100%) while definitions of ranks are the same as was used by NMFS for the SONCC Conservation Action Planning (CAP) workbooks (Kier Associates and NMFS 2008).

4 SUMMARY OF INDICATORS AND RECOMMENDED POPULATION-LEVEL STRESS AND THREAT RANKS

My recommended overall population-level ranks are presented in the maps in the Executive Summary at the beginning of this report. These ranks are now available for use in the recovery plan for SONCC coho salmon which is currently in development; however, NMFS will allow recovery plan authors to use their professional judgment to over-ride these ranks. Table 14 presents a summary of indicators and my recommended population-level ranks for the stress altered hydrologic function. The table also includes population-level findings regarding hydrologic stresses from the ODFW (2008) expert panel and the public draft 20012 NMFS coho salmon recovery plan. Indicators are based solely on data analyses (not professional judgment) and are presented at two different spatial scales, as appropriate: stream gages and coho salmon populations. Gage-level indicators were not averaged/aggregated to the population level. Rather, the recommended population-level ranks are based on my professional judgment that was informed by the gage-level indicators, population-level indicators, ODFW (2008) results, and the public draft 2012 recovery plan. Table 15 is similarly formatted, presenting indicators and my recommended population-level ranks for the threat dams and diversions.

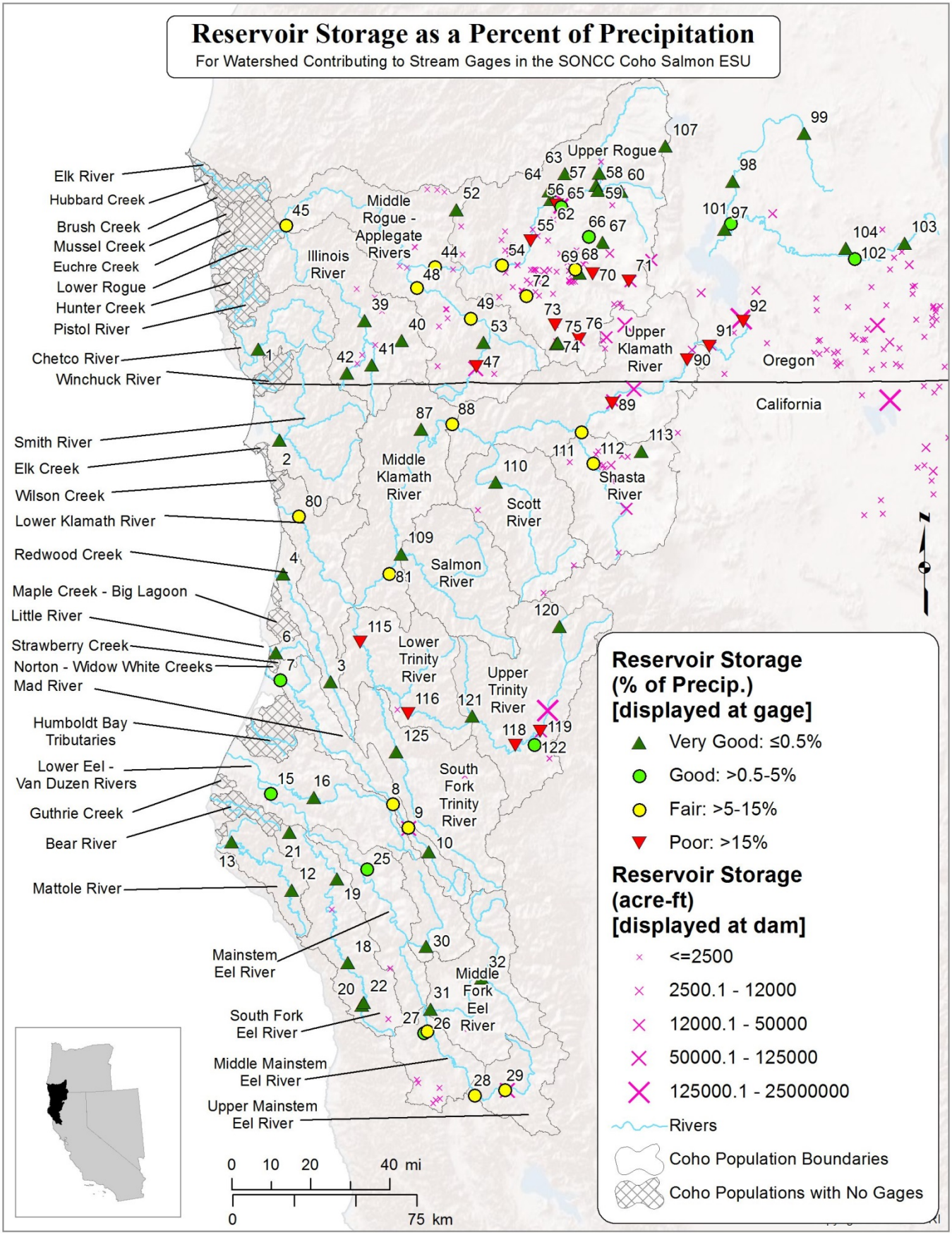

Figure 16. Map of reservoir storage in watersheds contributing to stream gages, expressed as a percent of annual precipitation. Gages are color-coded according to the rules in Table 2. Reservoir storage of each dam is also shown.

Table 13. Values and ratings for habitat blocked by dams and GIS-based watershed indicators of hydrologic function: reservoir volume (storage) as a percent of precipitation, human population density, agricultural area, impervious area, and road density.

Coho Population	Habitat blocked by dams		Reservoir Volume		Human Density		Agricultural Area		Impervious Area		Road Density	
Name	% of IP	rating	% of precip	rating	persons/km²	rating	% of area	rating	% of area	rating	mi per mi²	rating
Elk R	5.6	Good	0.0	Very Good	1.1	Good	3.16	Good	0.24	Very Good	2.12	Good
Brush	0.0	Very Good	0.0	Very Good	0.4	Very Good	0.00	Very Good	0.39	Very Good	2.88	Fair
Mussel	0.0	Very Good	0.0	Very Good	1.5	Good	0.05	Very Good	0.69	Very Good	3.73	Poor
Lwr Rogue	0.0	Very Good	0.0	Very Good	2.8	Good	0.10	Very Good	0.49	Very Good	3.61	Poor
Hunter	0.0	Very Good	0.0	Very Good	5.3	Fair	0.02	Very Good	0.73	Very Good	3.23	Poor
Pistol	0.0	Very Good	0.0	Very Good	0.3	Very Good	0.49	Very Good	0.23	Very Good	2.76	Fair
Chetco	0.0	Very Good	0.0	Very Good	6.5	Fair	0.13	Very Good	0.30	Very Good	1.89	Good
Winchuck	0.0	Very Good	0.0	Very Good	4.9	Good	0.31	Very Good	0.11	Very Good	2.41	Good
Smith	0.0	Very Good	0.0	Very Good	10.5	Fair	1.67	Very Good	0.47	Very Good	3.39	Poor
Elk Cr	0.0	Very Good	0.0	Very Good	261.0	Poor	0.51	Very Good	13.96	Fair	15.69	Poor
Wilson	0.0	Very Good	0.0	Very Good	23.3	Fair	0.00	Very Good	0.66	Very Good	6.98	Poor
Lwr Klamath	0.0	Very Good	0.0	Very Good	1.4	Good	0.15	Very Good	0.12	Very Good	6.27	Poor
Redwood	0.0	Very Good	0.0	Very Good	0.8	Very Good	0.44	Very Good	0.09	Very Good	8.07	Poor
Maple/Big Lagoon	7.8	Good	0.4	Very Good	0.1	Very Good	0.00	Very Good	0.01	Very Good	9.68	Poor
Little	0.0	Very Good	0.0	Very Good	5.5	Fair	2.51	Good	0.16	Very Good	10.29	Poor
Strawberry	0.0	Very Good	0.0	Very Good	103.9	Poor	7.94	Fair	1.36	Very Good	10.77	Poor
Norton/Widow White	0.0	Very Good	0.0	Very Good	435.2	Poor	0.00	Very Good	9.21	Good	13.26	Poor
Mad	0.0	Very Good	2.8	Good	9.8	Fair	0.40	Very Good	0.29	Very Good	5.15	Poor
Humboldt Bay Tribs	0.0	Very Good	0.0	Very Good	60.0	Poor	6.25	Fair	1.58	Very Good	12.59	Poor
Lwr Eel/Van Duz	0.0	Very Good	0.0	Very Good	13.6	Fair	5.65	Fair	0.44	Very Good	7.43	Poor
Guthrie	0.0	Very Good	0.0	Very Good	0.6	Very Good	0.00	Very Good	0.07	Very Good	4.39	Poor
Bear	0.0	Very Good	0.0	Very Good	0.2	Very Good	0.00	Very Good	0.08	Very Good	4.73	Poor
Mattole	0.0	Very Good	0.0	Very Good	1.9	Good	0.00	Very Good	0.07	Very Good	2.96	Fair
Illinois	3.3	Good	0.1	Very Good	3.8	Good	0.96	Very Good	0.30	Very Good	2.73	Fair
Mid Rogue/AppleG	9.3	Good	2.3	Good	19.4	Fair	2.01	Good	0.88	Very Good	3.77	Poor
Upr Rogue	15.5	Fair	11.6	Fair	31.4	Poor	6.75	Fair	1.07	Very Good	4.64	Poor
Mid Klamath	0.0	Very Good	0.0	Very Good	0.8	Very Good	0.02	Very Good	0.12	Very Good	2.18	Good
Upr Klamath	43.4	Poor	10.6	Fair	0.8	Very Good	1.11	Very Good	0.32	Very Good	2.92	Fair
Salmon	0.0	Very Good	0.0	Very Good	0.1	Very Good	0.00	Very Good	0.03	Very Good	1.61	Good
Scott	0.0	Very Good	0.0	Very Good	2.5	Good	4.79	Good	0.21	Very Good	2.92	Fair
Shasta	30.2	Fair	4.9	Good	10.3	Fair	15.09	Poor	1.06	Very Good	2.49	Good
SF Trinity	0.0	Very Good	0.0	Very Good	1.3	Good	0.04	Very Good	0.09	Very Good	3.24	Poor
Lwr Trinity	0.0	Very Good	0.0	Very Good	3.2	Good	0.12	Very Good	0.13	Very Good	2.41	Good
Upr Trinity	46.5	Poor	72.6	Poor	2.7	Good	0.00	Very Good	0.15	Very Good	2.36	Good
SF Eel	0.0	Very Good	0.1	Very Good	5.0	Fair	0.06	Very Good	0.17	Very Good	3.90	Poor
Main Eel	0.0	Very Good	0.0	Very Good	1.0	Good	0.00	Very Good	0.05	Very Good	3.33	Poor
Mid Fork Eel	0.0	Very Good	0.1	Very Good	1.3	Good	0.00	Very Good	0.09	Very Good	2.55	Fair
Mid Main Eel	4.5	Good	0.3	Very Good	14.2	Fair	1.67	Very Good	0.23	Very Good	4.45	Poor
Upr Main Eel	79.6	Poor	8.0	Fair	0.3	Very Good	0.00	Very Good	0.07	Very Good	2.80	Fair

Table 14. Summary for altered hydrologic function stress for each population and life stage: 1) indicator ranks [VG = very good, G = good, F = fair, P = poor], 2) limiting factor/stress rankings from ODFW (2008) expert panel [VH = primary concern, H =secondary concern, L = not primary or secondary concern], 3) stress ranks from 2012 public draft NMFS recovery plan [L= low, M = medium, H = high, VH = very high], 4) My recommendations for stress ranks for upcoming final NMFS recovery plan [VG = very good, G = good, F = fair, P = poor].

Life Stages Affected →		All	Juv	Juv	Juv	All	All	All	All	Juv	Juv	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →		Indicators								ODFW Panel		2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	Reservoir volume	Trend: Min. 30-d flow	Trend: Sept. Flow Accounting for Precip.	Water Use (%30-d flow)	Human Density	Agricultural Area	Impervious Area	Road Density	Water Management on Habitat Access	Water Management on Water Quality	Altered Hydrologic Function Stress Rank						Altered Hydrologic Function Stress Rank						Notes
Elk R	population-wide	VG				G	G	VG	G	-	H	H	H	H	M	M	H	L	L	H	M	M	M	Diversions and impoundments affect water temperature in the tributaries with highest IP
Brush	population-wide	VG				VG	VG	VG	F	-	-	L	L	L	L	-	L	L	L	L	L	L	L	
Mussel	population-wide	VG				G	VG	VG	P			L	L	L	L	-	L	L	M	M	L	L	M	High road densities, timber harvest, and Highway 101 channelization likely affect runoff patterns
Lwr Rogue	population-wide	VG				G	VG	VG	P	-	-	M	M	M	L	L	M	M	M	M	L	L	M	Diversions could affect water temperature in Edson and Indian Creek
Hunter	population-wide	VG				F	VG	VG	P			L	L	L	L	-	L	M	M	M	M	L	M	High road densities and timber harvest likely affect runoff patterns. Diversions likely affect water temps.
Pistol	population-wide	VG				VG	VG	VG	F	-	-	H	H	H	H	-	H	M	M	M	M	L	M	
Chetco	population-wide	VG				F	VG	VG	G	-	-	H	H	VH	M	M	VH	M	H	H	M	L	H	See dams/diversions notes. Urbanization in estuary and high IP estuarine tributary Tuttle Creek.
	Chetco R (14400000)	VG	VG	VG	VG																			
Winchuck	population-wide	VG				G	VG	VG	G	-	-	M	VH	VH	M	H	VH	M	H	H	M	L	H	See dams/diversions notes. USGS maps show intermittent flow at mouth of SF Winchuck (highest IP in basin).
Smith	population-wide	VG				F	VG	VG	P			L	L	L	L	-	L	L	L	L	L	L	L	
	Smith R (11532500)	VG	VG	VG	VG																			
Elk Cr	population-wide	VG				P	VG	F	P			L	M	M	M	-	M	L	M	M	M	L	M	Relatively high impervious area compared to other populations within the ESU, but few diversions
Wilson	population-wide	VG				F	VG	VG	P			M	M	M	M	-	M	M	M	M	M	L	M	
Lwr Klamath	population-wide	VG				G	VG	VG	P			M	M	H	H	H	H	M	M	H	H	H	H	
	Klamath R Klamath (11530500)	F	VG	VG	P																			
	Klamath R Accr: Klamath - Orl - TrinityR (c11530500_11523000_t1)	VG	VG	VG	G																			
Redwood	population-wide	VG				VG	VG	VG	P			M	M	M	L	-	M	M	M	H	L	M	M	Late summer and fall flows show significant long-term declines at both Redwood Creek gages. Declines are only partly explained by precip (and even less so by diversions). Most high IP habitat is in Prairie Creek, which has less landscape alteration and less diversions and thus likely is not experiencing the same flow declines.
	Redwood Cr Blue Lake (11481500)	VG	P	P	VG																			
	Redwood Cr Orick (11482500)	VG	P	F	G																			
	Redwood Cr Accr: Orick - 299 (c11482500_11481500)	VG	P	P	G																			
Maple/ Big Lagoon	population-wide	VG				VG	VG	VG	P			L	M	H	H	M	M	L	M	H	M	M	M	Highway acts as a levee and affects flow dynamics. Changed smolt rank from H to M, because M seems to be the appropriate overall rank, but under the scoring rules, two H life stages results in H overall rank
Little	population-wide	VG				F	G	VG	P			L	M	M	L	-	M	L	M	M	L	L	M	

Life Stages Affected →		All	Juv	Juv	Juv	All	All	All	All	Juv	Juv	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →		Indicators								ODFW Panel		2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	Reservoir volume	Trend: Min. 30-d flow	Trend: Sept. Flow Accounting for Precip.	Water Use (%30-d flow)	Human Density	Agricultural Area	Impervious Area	Road Density	Water Management on Habitat Access	Water Management on Water Quality	Altered Hydrologic Function Stress Rank						Altered Hydrologic Function Stress Rank						Notes
	Little R (11481200)	VG	VG	VG	G																			
Strawberry	population-wide	VG				P	F	VG	P			M	M	M	M	-	M	M	M	M	M	L	M	
Norton/ Widow White	population-wide	VG				P	VG	G	P			M	M	M	M	-	M	M	M	M	M	L	M	More impervious areas than most populations in ESU, but few diversions
Mad	population-wide	G				F	VG	VG	P			M	M	M	M	-	M	M	M	M	M	L	M	Humboldt Bay Municipal Water District (HBMWD) diversion is located upstream of Arcata gage, so accretions between Arcata and Ruth gages cannot be used to assess tributary flows (without accounting for the HBMWD diversion).
	Mad R Arcata (11481000)	G	VG	VG	G																			
	Mad R Forest Glen (11480500)	F			VG																			
	Mad R Bl Ruth Res (11480410)	F			VG																			
	Mad R Ab Ruth Res (11480390)	VG			NA																			
	Mad R Accr: Arcata - Bl Ruth Res (c11481000_11480410)	VG			P																			
Humboldt Bay Tributaries	population-wide	VG				P	F	VG	P			M	M	M	M	-	M	M	M	M	M	L	M	
Lwr Eel/ Van Duz	population-wide	VG				F	F	VG	P			L	L	L	L	-	L	L	M	H	M	L	M	Draft 2012 ranks were too low. Scientific understanding of surface/ground water interactions in lacking, but water use (from groundwater pumping, and to a lesser extent surface water diversions) likely affects flow and water temperature in high-IP tributaries to the lower Van Duzen River and lower Eel River (and potentially other high-IP areas such as Larabee Creek's headwaters). It could also substantially reduce accretions of cool groundwater to alluvial reaches of the mainstem Eel and mainstem Van Duzen. CDWR estimates annual crop water use (average 1998 to 2005) as 28,000 AF in the Lower Eel and 3,500 AF in the Van Duzen River, which if applied evenly across a 6-month irrigation season equates to 77 and 10 cfs, respectively. In comparison, the 7d minimum streamflow (median for 1981-2010) is 87 cfs for Eel River at Scotia and 7.5 cfs for Van Duzen River at Bridgeville.
	Eel R Scotia (11477000)	G	F	F	P																			
	Van Duzen R (11478500)	VG	F	F	G																			
	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)	VG	VG	VG	F																			
Guthrie	population-wide	VG				VG	VG	VG	P			L	L	L	L	L	L	L	L	L	L	L	L	
Bear	population-wide	VG				VG	VG	VG	P			L	M	M	L	-	L	L	L	M	L	L	L	
Mattole	population-wide	VG				G	VG	VG	F			L	M	VH	VH	H	VH	L	M	VH	VH	H	VH	Summer and fall flows show significant long-term declines at Petrolia gage. Declines are only partly explained by precip (and even less so by diversions).
	Mattole R Ettersburg (11468900)	VG			G																			
	Mattole R Petrolia (11469000)	VG	F	F	G																			
	Mattole R Accr: Petrolia - Ettersburg (c11469000_11468900)	VG			G																			
Illinois	population-wide	VG				G	VG	VG	F	VH	VH	VH	VH	VH	VH	H	VH	M	VH	VH	VH	H	VH	Many studies have found flows to the most limiting factor for

Life Stages Affected →	All	Juv	Juv	Juv	All	All	All	All	Juv	Juv	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →	Indicators								ODFW Panel		2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	Reservoir volume	Trend: Min. 30-d flow	Trend: Sept. Flow Accounting for Precip.	Water Use (%30-d flow)	Human Density	Agricultural Area	Impervious Area	Road Density	Water Management on Habitat Access	Water Management on Water Quality	Altered Hydrologic Function Stress Rank						Altered Hydrologic Function Stress Rank						Notes
	Illinois R Kerby (14377100)	VG	VG	VG	P																			fisheries, coho salmon habitat to be dewatered, and water quality impairment as a result of flow depletion (see population profile for details). The stream gage at Kerby (located downstream of agricultural diversions and high-IP habitat) does not show declining flows in any month except September, and that decline is due to precipitation not local factors; however, human water use is high relative to minimum 7d streamflow, reflecting a long history of water use. Watershed upstream of Sucker Cr. gage is mostly un-inhabited federal lands, but summer/fall streamflows (with effects of precip accounted for) are nonetheless declining.
	Sucker Cr (14375100)	VG	VG	F	VG																			
	EF Illinois R (14372500)	VG	VG	VG	G																			
	WF Illinois R (14375500)	VG			VG																			
	Illinois R Accr: Kerby - EF - Sucker Cr (c14377100_14372500_t1)	VG	VG	VG	P																			
Mid Rogue/ AppleG	population-wide	G				F	G	VG	P	VH	VH	VH	VH	VH	VH	M	VH	M	VH	VH	VH	H	VH	Construction and operation of dams has resulted in higher summer baseflows than before the dams, in part due to irrigation conveyance. Human water use is very high relative to minimum 7d streamflow.
	Rogue R Grants Pass (14361500)	F	VG	VG	F																			
	Rogue R Agness (14372300)	F	VG	VG	F																			
	Rogue R Accr: Agness - Grants Pass (c14372300_14361500_t1)	VG	VG	VG	P																			
	Applegate R Copper (14362000)	P	VG	VG	VG																			
	Applegate R Wilderville (14369500)	F			F																			
	Applegate R Applegate (14366000)	F	VG	VG	G																			
	Applegate R Accr: Wilderville - Applgt (c14369500_14366000)	VG			P																			
	Applegate R Accr: Applgt - Copper (c14366000_14362000)	VG			P																			
	Grave Cr (14371500)	VG			VG																			
	Star Gulch (14362250)	VG			G																			
Upr Rogue	population-wide	F				P	F	VG	P	VH	VH	VH	VH	VH	VH	VH	VH	H	VH	VH	VH	H	VH	Many stream gages are on regulated mainstem or above anadromy on tributaries, but Elk Cr near Trail (14338000) and Big Butte Cr Near Mcleod (14337500) are long-term gages near mouths of important coho streams (both show declining trend in almost every month for flow with effect of precip accounted for). NF L Butte Cr Nr LakeCr (14343000) and NF L Butte Cr At F L Nr LakeCr (14342500) also have declining trends in flow with effect of precip accounted for. Summer flows show increasing trend at most mainstem Rogue River gages (due to releases from dams) except those above Lost Creek Dam, which show decreasing trend.
	Rogue R At Raygold (14359000)	F	VG	VG	F																			
	Rogue R Dodge Bridge (14339000)	P	VG	VG	VG																			
	Rogue R Near Mcleod (14337600)	P	VG	VG	VG																			
	Rogue R Blw Prospect (14330000)	VG	F	F	VG																			
	Rogue R Abv Prospect (14328000)	VG	F	G	P																			
	SF Rogue R S Prospect (14334700)	VG			VG																			
	SF Rogue R Nr Prospect (14332000)	VG	VG	VG	VG																			
	Elk Cr Trail (14338000)	VG	VG	F	G																			
	Elk Cr Cascade Gorge (14337800)	VG			VG																			
	WB Elk Cr Trail (14337870)	VG			VG																			
	Big Butte Cr Near Mcleod (14337500)	G	VG	G	G																			

Life Stages Affected →	All	Juv	Juv	Juv	All	All	All	All	Juv	Juv	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →	Indicators								ODFW Panel		2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	Reservoir volume	Trend: Min. 30-d flow	Trend: Sept. Flow Accounting for Precip.	Water Use (%30-d flow)	Human Density	Agricultural Area	Impervious Area	Road Density	Water Management on Habitat Access	Water Management on Water Quality	Altered Hydrologic Function Stress Rank						Altered Hydrologic Function Stress Rank						Notes
	SF Big Butte Cr Nr Butte Falls (14335500)	G			VG																			
	SF Big Butte Cr Ab Willow Cr (14335200)	VG	VG	G	G																			
	Little Butte Cr At LakeCr (14346700)	F			F																			
	SF Little Butte Cr Nr LakeCr (14341500)	VG			G																			
	NF L Butte Cr Nr LakeCr (14343000)	P	VG	VG	VG																			
	NF L Butte Cr At F L Nr LakeCr (14342500)	P	VG	VG	P																			
	Bear Cr At Medford (14357500)	F	VG	VG	P																			
	Bear Cr Blw Ashland Cr (14354200)	P			P																			
	WF Ashland Cr Near Ashland (14353000)	VG			P																			
	EF Ashland Cr Near Ashland (14353500)	VG			P																			
	Emigrant Cr Nr Ashland (14350000)	P			P																			
	NF L Butte Cr Accr: Nr Lake Cr - Falls (c14343000_14342500)	VG			VG																			
	Rogue R Accr: Raygold - Mcleod (c14359000_14337600)	G	P	VG	P																			
	Rogue R Accr: Raygold - Dodge Br (c14359000_14339000)	F	P	VG	P																			
Mid Klamath	population-wide	VG				VG	VG	VG	G			L	L	H	H	M	H	L	L	H	H	M	H	Hydrology of mainstem Klamath is more altered than tributaries. Combined flows of ungaged tributaries between Seiad, Orleans, and Klamath (calculated from accretions between gages) show a significant long-term decline only in the month of February; trend in flow with effects of precip accounted for is positive for many months.
	Klamath R Orleans (11523000)	F	G	G	P																			
	Klamath R Accr: Klamath - Orl - TrinityR (c11530500_11523000_t1)	VG	VG	VG	G																			
	Klamath R Accr: Orl - Sei - SalmR (c11523000_11520500_t2)	VG	VG	VG	VG																			
	Indian C (11521500)	VG	VG	VG	VG																			
Upr Klamath	population-wide	F				VG	VG	VG	F			L	M	VH	H	H	H	L	M	VH	H	H	H	Hydrology of mainstem Klamath is more altered than tributaries. Combined flows of ungaged tributaries between Iron Gate and Seiad (calculated from accretions between gages) show a significant long-term decline only in the months of February and November; trend in flow with effects of precip accounted for is negative only in November. Flows at groundwater-dominated gages upstream of Upper Klamath Lake are declining in many months (on an absolute basis and well as with the effects of precip accounted for).
	Klamath R Seiad Valley (11520500)	F	G	F	P																			
	Klamath R Iron Gate Dam (11516530)	P	VG	G	P																			
	Klamath R JCB Pwrplnt (11510700)	P	VG	F	P																			
	Klamath R Keno (11509500)	P	VG	P	P																			
	Link R Klamath Falls (11507500)	P	VG	VG	P																			
	Klamath R Accr: Sei - IG - ShastR - ScottR (c11520500_11516530_t1)	VG	VG	VG	F																			
	Klamath R Accr: Boyle - Keno (c11510700_11509500)	G	VG	VG	G																			
	Williamson R Blw Sprague R (11502500)	VG	F	F	F																			
	Williamson R Klamath Agency (11493500)	VG			NA																			

Life Stages Affected →	All	Juv	Juv	Juv	All	All	All	All	Juv	Juv	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →	Indicators								ODFW Panel		2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	Reservoir volume	Trend: Min. 30-d flow	Trend: Sept. Flow Accounting for Precip.	Water Use (%30-d flow)	Human Density	Agricultural Area	Impervious Area	Road Density	Water Management on Habitat Access	Water Management on Water Quality	Altered Hydrologic Function Stress Rank						Altered Hydrologic Function Stress Rank						Notes
	Williamson R Sheep Cr (11491400)	VG			VG																			
	Williamson R Accr: Bl Sprg - SprgR - K Mrsh (c11502500_11493500_t1)	VG	F	VG	VG																			
	Sprague R Chiloquin (11501000)	G	P	F	P																			
	Sprague R Beatty (11497500)	G	F	G	F																			
	NF Sprague R Power Plant (11495800)	VG			P																			
	Sycan R Snake Cr (11499100)	VG			P																			
	Sprague R Accr: Chiloquin - Beatty (c11501000_11497500)	VG	P	P	P																			
	Sprague R: Williamson R - Sprague (c11502500_11501000)	VG	F	G	G																			
	Annie Spring (11503000)	VG			P																			
Salmon	population-wide	VG				VG	VG	VG	G			L	L	M	L	L	M	L	L	M	L	L	L	Salmon River gage shows a significant long-term decline only in the month of February; trend in flow with effects of precip accounted for is positive for many months. Changed overall rank to L, to reflect new calculation method (overall rank is medium only if >=2 life stages with M rank).
	Salmon R (11522500)	VG	VG	VG	VG																			
Scott	population-wide	VG				G	G	VG	F			VH	VH	VH	VH	M	VH	H	VH	VH	VH	M	VH	Significant declines in summer/fall flows not explained by precip. Human water use is much larger than min 30d streamflow. Changed Egg rank from VH to H.
	Scott R Ft Jones (11519500)	VG	P	P	P																			
Shasta	population-wide	G				F	P	VG	G			M	VH	VH	VH	M	VH	M	VH	VH	VH	M	VH	Human water use is much larger than min 30d streamflow.
	Shasta R Yreka (11517500)	F	VG	G	P																			
	Shasta R Montague (11517000)	F			P																			
	Little Shasta R Montague (11516900)	VG																						
	Shasta R Accr: Yreka - Montague (c11517500_11517000)	VG			P																			
SF Trinity	population-wide	VG				G	VG	VG	P			M	H	H	M	H	H	M	H	H	M	H	H	
	SF Trinity Hyampom (11528700)	VG	VG	VG	G																			
Lwr Trinity	population-wide	VG				G	VG	VG	G			M	M	H	H	H	H	M	M	H	H	H	H	Combined flows of ungaged tributaries between Burnt Ranch and Hoopa (calculated from accretions between gages) show no significant long-term trends in flow or flow with effects of precip accounted for. Mainstem flows have increased in recent decades due to a decrease in water exports to the Central Valley.
	Trinity R Hoopa (11530000)	P	VG	VG	VG																			
	Trinity R Burnt Ranch (11527000)	P	VG	VG	VG																			
	Trinity R Accr: Hoopa - Burnt Ranch - SF (c11530000_11527000_t1)	VG	VG	VG	VG																			
	Trinity R Accr: Burnt Ranch - Lewiston (c11527000_11525500)	VG	VG	VG	G																			
	Trinity R Accr: Hoopa - Lewiston (c11530000_11525500)	VG	VG	VG	G																			

Life Stages Affected →		All	Juv	Juv	Juv	All	All	All	All	Juv	Juv	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →		Indicators								ODFW Panel		2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	Reservoir volume	Trend: Min. 30-d flow	Trend: Sept. Flow Accounting for Precip.	Water Use (%30-d flow)	Human Density	Agricultural Area	Impervious Area	Road Density	Water Management on Habitat Access	Water Management on Water Quality	Altered Hydrologic Function Stress Rank						Altered Hydrologic Function Stress Rank						Notes
Upr Trinity	population-wide	P				G	VG	VG	G			L	VH	VH	H	M	H	L	H	VH	H	M	H	Combined flows of ungaged tributaries between Lewiston and Burnt Ranch (calculated from accretions between gages) shows no significant long-term trends in flow; trend in flow with effects of precip accounted for is negative for June and August. Mainstem flows have increased in recent decades due to a decrease in water exports to the Central Valley. Alteration of the winter/spring hydrograph resulting from dam operations has degraded habitat complexity for fry and juveniles.
	Trinity R Limekiln Glch (11525655)	P			VG																			
	Trinity R Lewiston (11525500)	P	VG	VG	VG																			
	Trinity R Coffee Cr (11523200)	VG	VG	VG	VG																			
	NF Trinity R Helena (11526500)	VG																						
	Grass Valley Cr Fawn Lodge (11525600)	G			VG																			
	Trinity R Accr: Burnt Ranch - Lewiston (c11527000_11525500)	VG	VG	VG	G																			
	Trinity R Accr: Hoopa - Lewiston (c11530000_11525500)	VG	VG	VG	G																			
SF Eel	population-wide	VG				F	VG	VG	P			M	H	H	H	M	H	M	H	H	H	M	H	Late summer and fall flows show significant long-term declines at most gages in South Fork population. Declines are only partly explained by precip (Elder Creek is an exception, as is [almost] Leggett) and even less so by diversions. Greater declines at Miranda than Leggett. Ten Mile Creek went dry in 2012, but did not in 1996-1997 (Higgins 2013). Stress is H not VH because there are some geographic areas where stress is lower.
	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)	VG	VG	VG	F																			
	SF Eel R At Leggett (11475800)	VG	F	G	G																			
	SF Eel R Nr Miranda (11476500)	VG	P	F	G																			
	Bull Cr (11476600)	VG	P	P	VG																			
	Elder Cr (11475560)	VG	F	VG	VG																			
	SF Eel R Accr: Miranda - Leggett (c11476500_11475800)	VG	P	P	G																			
	Eel R Accr: Scotia - Van Ars (c11477000_11471500)	VG	P	F	P																			
	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)	VG	P	F	P																			
Main Eel	population-wide	VG				G	VG	VG	P			M	H	VH	H	M	M	M	H	VH	H	M	H	Water use calculations for gages within this population are highly affected by Outlet Creek (which is upstream from this population). Flows are critically low in summer, so rating for juveniles is appropriate. Changed overall rank to H, to reflect new calculation method (if there are 2 life stages with H rank, overall rank is a H)
	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)	VG	VG	VG	F																			
	Eel R Fort Seward (11475000)	G	VG	VG	P																			
	Eel R Accr: Scotia - Van Ars (c11477000_11471500)	VG	P	F	P																			
	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)	VG	P	F	P																			
	Eel R Accr: Ft Sew - Van Ars - MF (c11475000_11471500_t1)	VG	P	P	P																			
	Eel R Accr: Ft Sew - DRios - MF - Outl (c11475000_11472150_t1)	VG			G																			
	Eel R Accr: Dos Rios - Van Ars	VG			P																			

Life Stages Affected →		All	Juv	Juv	Juv	All	All	All	All	Juv	Juv	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →		Indicators								ODFW Panel		2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	Reservoir volume	Trend: Min. 30-d flow	Trend: Sept. Flow Accounting for Precip.	Water Use (%30-d flow)	Human Density	Agricultural Area	Impervious Area	Road Density	Water Management on Habitat Access	Water Management on Water Quality	Altered Hydrologic Function Stress Rank						Altered Hydrologic Function Stress Rank						Notes
	(c11472150_11471500)																							
Mid Fork Eel	population-wide	VG				G	VG	VG	F			M	M	M	M	M	M	M	M	M	M	M	M	
	MF Eel R (11473900)	VG	VG	VG	G																			September is the only month showing significant long-term declines at MF Eel gage (and there is no months with declining trend in flow with effect of precip accounted for)
	Black Butte R (11472900)	VG			VG																			
	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)	VG	P	F	P																			
Mid Main Eel	population-wide	VG				F	VG	VG	P			M	H	H	H	-	H	M	VH	VH	H	L	VH	Outlet Creek gage record was not long enough (1957-1994) to run 1953-2012 trend test, but trend test for 1957-1994 showed significant declines for several months including July and September for both flow and flow with effect of precip accounted for (see details in Appendix E). Outlet Creek first went dry in 1977 and was dry in many later years including some with relatively moderate precip. Tomki Creek was dry by June 14, 2012 (Higgins 2013) in contrast to having year-round water in 1996 (Friedrichsen 1998). Intuitively, severe stress for juveniles (drying streams) should be enough to justify VH overall stress, however scoring rules require 2 VH life stages to have VH overall stress. Therefore fry stress was elevated from H to VH, which is justified in part because in years with delayed spawning/emergence and dry spring seasons, streamflows could be low enough in May/June prior to severely affect fry prior to the transition to juveniles.
	Eel R Dos Rios (11472150)	F			G																			
	Outlet Cr (11472200)	G			P																			
	Eel R Accr: Scotia - Van Ars (c11477000_11471500)	VG	P	F	P																			
	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)	VG	P	F	P																			
	Eel R Accr: Ft Sew - Van Ars - MF (c11475000_11471500_t1)	VG	P	P	P																			
	Eel R Accr: Dos Rios - Van Ars (c11472150_11471500)	VG			P																			
Upr Main Eel	population-wide	F				VG	VG	VG	F			L	M	H	H	L	M	L	M	H	H	L	H	Changed overall rank from M to H, to reflect new calculation method (if there are 2 life stages with H rank, overall rank is a H)
	Eel R Van Arsdale (11471500)	F	VG	VG	VG																			
	Eel R Scott Dam (11470500)	F	VG	F	VG																			

Table 15. Summary of dams and diversions threat for each population and life stage: indicator ranks [VG = very good, G = good, F = fair, P = poor], 2) limiting factor/stress rankings from ODFW (2008) expert panel [VH = primary concern, H =secondary concern, L = not primary or secondary concern], 3) threat ranks from 2012 public draft NMFS recovery plan [L= low, M = medium, H = high, VH = very high], 4) My recommendations for threat ranks for upcoming final NMFS recovery plan [VG = very good, G = good, F = fair, P = poor].

Life Stages Affected →		All	All	Juv	All	All	Juv	Juv	Fry	Juv	Smolt	Adult	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →		Indicators					ODFW Panel						2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	**Gage or Population**	**% Coho Habitat Inaccessible**	**Reservoir volume**	**Water Use (%30-d flow)**	**Agricultural Area**	**Human Density**	**Water Management on Water Quality**	**Water Management on Habitat Access**	**Water Management on Other Factors**			**Water Management on Habitat Access**	**Dams and Diversion Threat Rank**						**Dams and Diversion Threat Rank**						**Notes**
Elk R	population-wide	G	VG		G	G	H	L	L	L	L	L	-	H	H	H	H	H	L	M	H	H	M	H	Diversions and impoundments affect water temperature in the tributaries with highest IP. Dam on estuary trib blocks habitat.
Brush	population-wide	VG	VG		VG	VG	L	L	L	VH	L	L	-	L	L	L	L	L	L	M	M	L	L	M	Unscreened overflow channel diverts peak flows from Brush Creek off cliff into ocean, but only now occurs every 15 years
Mussel	population-wide	VG	VG		VG	G							L	M	M	M	M	M	L	L	M	L	L	L	Very few diversions
Lwr Rogue	population-wide	VG	VG		VG	G	L	L	L	L	L	L	L	M	M	M	L	M	L	M	M	M	L	M	Diversions could affect water temperature in Edson and Indian Cr. Libby Pond is impassable barrier but no IP upstream.
Hunter	population-wide	VG	VG		VG	F							L	M	M	M	M	M	L	M	M	M	L	M	
Pistol	population-wide	VG	VG		VG	VG	L	L	L	L	L	L	L	M	M	M	M	M	L	M	M	M	L	M	
Chetco	population-wide	VG	VG		VG	F	L	L	L	L	L	L	L	M	M	M	M	M	L	M	M	M	M	M	USGS gage is upstream from the largest diversion (municipal), so reflects only small subset of diversions. ODFW 1964 instream right pre-dates majority (43 of 59 cfs) of out-of-stream water rights (Maguire 2001 Chetco WA) but are still not met in many years. Jacks Cr & Chetco R mainstem above the N Fk identified by ODFW as Streamflow Restoration Priority Areas.
	Chetco R (14400000)		VG	VG																					
Winchuck	population-wide	VG	VG		VG	G	L	L	L	L	L	L	L	H	H	H	M	H	L	M	H	M	L	M	Oregon out-of-stream water rights are only 3.1 CFS. No water rights listed in Calif. but streamside ponds present along lower South Fork
Smith	population-wide	VG	VG		VG	F							L	L	L	L	L	L	L	L	L	L	L	L	USGS gage is upstream from most of the diversions and groundwater pumping.
	Smith R (11532500)		VG	VG																					
Elk Cr	population-wide	VG	VG		VG	P							L	L	L	L	L	L	L	L	L	L	L	L	
Wilson	population-wide	VG	VG		VG	F							L	L	L	L	L	L	L	L	L	L	L	L	No known diversions.
Lwr Klamath	population-wide	VG	VG		VG	G							M	M	H	H	H	H	L	M	H	H	H	H	
	Klamath R Klamath (11530500)		F	P																					
	Klamath R Accr: Klamath - Orl - TrinityR (c11530500_11523000_t1)		VG	G																					
Redwood	population-wide	VG	VG		VG	VG							M	M	M	M	M	M	L	M	M	M	M	M	Changed rank for Egg from M to L because diversions should not substantively affect flow during incubation
	Redwood Cr Blue Lake (11481500)		VG	VG																					
	Redwood Cr Orick (11482500)		VG	G																					
	Redwood Cr Accr: Orick - 299 (c11482500_11481500)		VG	G																					

Life Stages Affected →	All	All	Juv	All	All	Juv	Juv	Fry	Juv	Smolt	Adult	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →	Indicators					ODFW Panel						2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	% Coho Habitat Inaccessible	Reservoir volume	Water Use (%30-d flow)	Agricultural Area	Human Density	Water Management on Water Quality	Water Management on Habitat Access	Water Management on Other Factors		Water Management on Habitat Access	Dams and Diversion Threat Rank						Dams and Diversion Threat Rank						Notes
Maple/ Big Lagoon	population-wide	G	VG		VG	VG						M	M	M	M	M	M	L	M	M	M	M	M	Few diversions, but mill pond dam on Gray Cr. blocks high IP habitat. Changed rank for Egg from M to L because diversions should not substantively affect flow during incubation
Little	population-wide	VG	VG		G	F						M	M	M	M	L	M	L	M	M	M	L	M	Changed rank for Egg from M to L because diversions should not substantively affect flow during incubation
	Little R (11481200)		VG	G																				
Strawberry	population-wide	VG	VG		F	P						L	L	L	L	L	L	L	L	L	L	L	L	High human pop. obtains water from Mad R, not Straw. Cr.
Norton/ Widow White	population-wide	VG	VG		VG	P						L	M	M	M	M	M	L	M	M	M	L	M	High human population density obtains water from Mad R, not Norton/Widow White Cr.
Mad	population-wide	VG	G		VG	F						M	M	M	M	L	M	M	M	M	M	L	M	
	Mad R Arcata (11481000)		G	G																				
	Mad R Forest Glen (11480500)		F	VG																				
	Mad R Bl Ruth Res (11480410)		F	VG																				
	Mad R Ab Ruth Res (11480390)		VG	NA																				
	Mad R Accr: Arcata - Bl Ruth Res (c11481000_11480410)		VG	P																				
Humboldt Bay Tribs	population-wide	VG	VG		F	P						L	L	M	M	M	M	L	L	M	M	M	M	
Lwr Eel/ Van Duz	population-wide	VG	VG		F	F						H	H	H	M	H	H	L	H	H	M	H	H	Changed rank for Egg from H to L because diversions should not substantively affect flow during incubation. Low fall flows from Potter Valley Project diversion could affect adult migration. See Altered Hydrologic Function comments regarding water use/diversions.
	Eel R Scotia (11477000)		G	P																				
	Van Duzen R (11478500)		VG	G																				
	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)		VG	F																				
Guthrie	population-wide	VG	VG		VG	VG						L	L	L	L	L	L	L	L	L	L	L	L	
Bear	population-wide	VG	VG		VG	VG						L	L	L	L	L	L	L	L	L	L	L	L	
Mattole	population-wide	VG	VG		VG	G						H	VH	VH	H	H	VH	L	VH	VH	H	H	VH	Changed rank for Egg from H to L because diversions should not substantively affect flow during incubation.
	Mattole R Ettersburg (11468900)		VG	G																				
	Mattole R Petrolia (11469000)		VG	G																				
	Mattole R Accr: Petrolia - Ettersburg (c11469000_11468900)		VG	G																				
Illinois	population-wide	G	VG		VG	G	VH	VH	H	H	H	H	M	VH	VH	VH	VH	VH	L	VH	VH	VH	H	VH	See altered hydrologic function comments regarding flows. Dams & diversion structures block access to some tribs for juveniles & adults. Diversions entrain fry, juveniles, & smolts. Changed rank for Adult from VH to H because only 3% habitat is blocked by dams: McMullin Cr Dam (Lake
	Illinois R Kerby (14377100)		VG	P																				
	Sucker Cr (14375100)		VG	VG																				
	EF Illinois R (14372500)		VG	G																				
	WF Illinois R (14375500)		VG	VG																				

Life Stages Affected →		All	All	Juv	All	All	Juv	Juv	Fry	Juv	Smolt	Adult	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →		Indicators					ODFW Panel						2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	% Coho Habitat Inaccessible	Reservoir volume	Water Use (%30-d flow)	Agricultural Area	Human Density	Water Management on Water Quality	Water Management on Habitat Access	Water Management on Other Factors			Water Management on Habitat Access	Dams and Diversion Threat Rank						Dams and Diversion Threat Rank						Notes
	Illinois R Accr: Kerby - EF - Sucker Cr (c14377100_14372500_t1)		VG	P																					Selmac)(trib to Deer Cr) & Tall Timber Lake on Salt Gulch Cr (trib to Deer Cr). Changed rank for Egg from M to L because diversions should not substantively affect flow during incubation.
Mid Rogue/ AppleG	population-wide	G	G		G	F	VH	VH	H	H	H	H	H	VH	VH	VH	H	VH	L	VH	VH	VH	H	VH	Changed rank for Egg from H to L because diversions should not substantively affect flow during incubation. Applegate Dam on Applegate R, Strong Reservoir on Sour Dough Gulch (trib to Wolf Cr), Madams Creek Dam on Madams Cr, Lippert Reservoir on Camp Meeting Cr (trib to Williams Cr), Winningham Reservoir Dam on Forest Cr (trib to Applegate R), un-named dam on Poormans Cr (trib to Forest Cr).
	Rogue R Grants Pass (14361500)		F	F																					
	Rogue R Agness (14372300)		F	F																					
	Rogue R Accr: Agness - Grants Pass (c14372300_14361500_t1)		VG	P																					
	Applegate R Copper (14362000)		P	VG																					
	Applegate R Wilderville (14369500)		F	F																					
	Applegate R Applegate (14366000)		F	G																					
	Applegate R Accr: Wilderville - Applgt (c14369500_14366000)		VG	P																					
	Applegate R Accr: Applgt - Copper (c14366000_14362000)		VG	P																					
	Grave Cr (14371500)		VG	VG																					
	Star Gulch (14362250)		VG	G																					
Upr Rogue	population-wide	F	F		F	P	VH	VH	H	H	H	H	M	M	H	H	H	H	M	H	VH	VH	H	VH	See altered hydrologic function comments regarding flows. Dams and diversion structures block access to some tributaries for juveniles and adults. Diversions entrain fry, juveniles, and smolts. Despite recent dam removals, 15% of IP habitat is still completely blocked by dams and there are many additional partial barriers. Diversions are a very significant issue for summer juveniles (increasing water temperature and drying streams) and smolts so rank increased to VH. The following dams block IP habitats: Lost Creek reservoir on Rogue R, Rounds reservoir on Emigrant Cr (short distance downstream of Emigrant Reservoir), Talent Irrigate District west lateral on Anderson Creek, Agate Reservoir on Antelope Cr, Fish Lake, un-named dam on Queens Branch of Pleasant Creek, Un-named dam on May Creek (trib to Evans Cr), Hammel No. 2 dam on Murderer's Gulch (trib to Reese Cr), un-named dam on Indian Creek, Yankee Reservoir (Gardener Reservoir) on Yankee Cr, Woolfolk Reservoir on Schoolhouse Cr (trib to Little Butte Cr), Charles Stanley reservoir on Unnamed trib to Little Butte Cr, Obsborne Cr Dam on Osborne Cr (trib to Little Butte Cr),
	Rogue R At Raygold (14359000)		F	F																					
	Rogue R Dodge Bridge (14339000)		P	VG																					
	Rogue R Near Mcleod (14337600)		P	VG																					
	Rogue R Blw Prospect (14330000)		VG	VG																					
	Rogue R Abv Prospect (14328000)		VG	P																					
	SF Rogue R S Prospect (14334700)		VG	VG																					
	SF Rogue R Nr Prospect (14332000)		VG	VG																					
	Elk Cr Trail (14338000)		VG	G																					
	Elk Cr Cascade Gorge (14337800)		VG	VG																					
	WB Elk Cr Trail (14337870)		VG	VG																					
	Big Butte Cr Near Mcleod (14337500)		G	G																					
	SF Big Butte Cr Nr Butte Falls (14335500)		G	VG																					
	SF Big Butte Cr Ab Willow Cr (14335200)		VG	G																					
	Little Butte Cr At LakeCr (14346700)		F	F																					
	SF Little Butte Cr Nr LakeCr (14341500)		VG	G																					
	NF L Butte Cr Nr LakeCr (14343000)		P	VG																					
	NF L Butte Cr At F L Nr LakeCr (14342500)		P	P																					
	Bear Cr At Medford (14357500)		F	P																					
	Bear Cr Blw Ashland Cr (14354200)		P	P																					

Life Stages Affected →	All	All	Juv	All	All	Juv	Juv	Fry	Juv	Smolt	Adult	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →	Indicators					ODFW Panel						2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	% Coho Habitat Inaccessible	Reservoir volume	Water Use (%30-d flow)	Agricultural Area	Human Density	Water Management on Water Quality	Water Management on Habitat Access	Water Management on Other Factors		Water Management on Habitat Access	Dams and Diversion Threat Rank						Dams and Diversion Threat Rank						Notes
	WF Ashland Cr Near Ashland (14353000)		VG	P																				Willow Lake Dam on Willow Creek (trib to South Fork Big Butte Cr), Granite Street Reservoir Dam on Ashland Cr.
	EF Ashland Cr Near Ashland (14353500)		VG	P																				
	Emigrant Cr Nr Ashland (14350000)		P	P																				
	NF L Butte Cr Accr: Nr Lake Cr - Falls (c14343000_14342500)		VG	VG																				
	Rogue R Accr: Raygold - Mcleod (c14359000_14337600)		G	P																				
	Rogue R Accr: Raygold - Dodge Br (c14359000_14339000)		F	P																				
Mid Klamath	population-wide	VG	VG		VG	VG						L	M	H	H	M	M	L	M	H	H	M	H	Changed overall rank to H, to reflect new calculation method (if there are 2 life stages with H rank, overall rank is a H)
	Klamath R Orleans (11523000)		F	P																				
	Klamath R Accr: Klamath - Orl - TrinityR (c11530500_11523000_t1)		VG	G																				
	Klamath R Accr: Orl - Sei - SalmR (c11523000_11520500_t2)		VG	VG																				
	Indian C (11521500)		VG	VG																				
Upr Klamath	population-wide	P	F		VG	VG						VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	Mainstem dams completely block access to important upstream habitats such as Spencer Creek and the springs below J.C. Boyle Dam. Unscreened diversions affect fry and juveniles.
	Klamath R Seiad Valley (11520500)		F	P																				
	Klamath R Iron Gate Dam (11516530)		P	P																				
	Klamath R JCB Pwrplnt (11510700)		P	P																				
	Klamath R Keno (11509500)		P	P																				
	Link R Klamath Falls (11507500)		P	P																				
	Klamath R Accr: Sei - IG - ShastR - ScottR (c11520500_11516530_t1)		VG	F																				
	Klamath R Accr: Boyle - Keno (c11510700_11509500)		G	G																				
	Williamson R Blw Sprague R (11502500)		VG	F																				
	Williamson R Klamath Agency (11493500)		VG	NA																				
	Williamson R Sheep Cr (11491400)		VG	VG																				
	Williamson R Accr: Bl Sprg - SprgR - K Mrsh (c11502500_11493500_t1)		VG	VG																				
	Sprague R Chiloquin (11501000)		G	P																				
	Sprague R Beatty (11497500)		G	F																				
	NF Sprague R Power Plant (11495800)		VG	P																				
	Sycan R Snake Cr (11499100)		VG	P																				
	Sprague R Accr: Chiloquin - Beatty (c11501000_11497500)		VG	P																				

Life Stages Affected →	All	All	Juv	All	All	Juv	Juv	Fry	Juv	Smolt	Adult	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →	Indicators					ODFW Panel						2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	% Coho Habitat Inaccessible	Reservoir volume	Water Use (%30-d flow)	Agricultural Area	Human Density	Water Management on Water Quality	Water Management on Habitat Access	Water Management on Other Factors		Water Management on Habitat Access	Dams and Diversion Threat Rank						Dams and Diversion Threat Rank						Notes
	Sprague R: Williamson R - Sprague (c11502500_11501000)		VG	G																				
	Annie Spring (11503000)		VG	P																				
Salmon	population-wide	VG	VG		VG	VG						L	L	L	L	L	L	L	L	L	L	L	L	
	Salmon R (11522500)		VG	VG																				
Scott	population-wide	VG	VG		G	G						M	VH	VH	VH	VH	VH	M	VH	VH	VH	VH	VH	Most diversions are screened, but withdrawals of surface and groundwater do not leave sufficient instream flows
	Scott R Ft Jones (11519500)		VG	P																				
Shasta	population-wide	F	G		P	F						VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	Most diversions are screened, but withdrawals of surface and groundwater do not leave sufficient instream flows. The following dams block IP habitats: Dwinnell Dam on Shasta River and Greenhorn Dam on Greenhorn Cr.
	Shasta R Yreka (11517500)		F	P																				
	Shasta R Montague (11517000)		F	P																				
	Little Shasta R Montague (11516900)		VG																					
	Shasta R Accr: Yreka - Montague (c11517500_11517000)		VG	P																				
SF Trinity	population-wide	VG	VG		VG	G						M	H	VH	M	H	H	M	H	VH	M	H	H	
	SF Trinity Hyampom (11528700)		VG	G																				
Lwr Trinity	population-wide	VG	VG		VG	G						L	H	H	M	M	M	L	H	H	M	M	H	
	Trinity R Hoopa (11530000)		P	VG																				
	Trinity R Burnt Ranch (11527000)		P	VG																				
	Trinity R Accr: Hoopa - Burnt Ranch - SF (c11530000_11527000_t1)		VG	VG																				Changed overall rank to H, to reflect new calculation method (if there are 2 life stages with H rank, overall rank is a H)
	Trinity R Accr: Burnt Ranch - Lewiston (c11527000_11525500)		VG	G																				
	Trinity R Accr: Hoopa - Lewiston (c11530000_11525500)		VG	G																				
Upr Trinity	population-wide	P	P		VG	G						M	H	VH	H	VH	H	M	H	VH	H	VH	VH	
	Trinity R Limekiln Glch (11525655)		P	VG																				
	Trinity R Lewiston (11525500)		P	VG																				
	Trinity R Coffee Cr (11523200)		VG	VG																				
	NF Trinity R Helena (11526500)		VG																					
	Grass Valley Cr Fawn Lodge (11525600)		G	VG																				
	Trinity R Accr: Burnt Ranch - Lewiston (c11527000_11525500)		VG	G																				Lewiston/Trinity dams block access to majority of IP habitat in population (minor amount also blocked by Buckhorn Dam on Grass Valley Creek). Alteration of the winter/spring hydrograph resulting from dam operations has degraded habitat complexity for fry and juveniles. Changed overall rank to VH, to reflect new calculation method (if there are 2 life stages with VH rank, overall rank is a VH)
	Trinity R Accr: Hoopa - Lewiston (c11530000_11525500)		VG	G																				
SF Eel	population-wide	VG	VG		VG	F						H	H	H	M	H	H	L	H	H	M	H	H	Diversions do not explain the long-term declines in flow, but declining flows mean diversions will have more effect on fish than if flows had not declined. Human population density is variable in watershed (lower in Bull Creek, Hollow Tree
	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)		VG	F																				
	SF Eel R At Leggett (11475800)		VG	G																				

Life Stages Affected →	All	All	Juv	All	All	Juv	Juv	Fry	Juv	Smolt	Adult	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →	Indicators					ODFW Panel						2012 Public Draft NMFS Plan						My Recommendation for Final Plan						
Coho Population Name	Gage or Population	% Coho Habitat Inaccessible	Reservoir volume	Water Use (%30-d flow)	Agricultural Area	Human Density	Water Management on Water Quality	Water Management on Habitat Access	Water Management on Other Factors		Water Management on Habitat Access	Dams and Diversion Threat Rank						Dams and Diversion Threat Rank						Notes
	SF Eel R Nr Miranda (11476500)		VG	G																				Creek, upper mainstem South Fork Eel; higher in Salmon Creek, Redwood Creek, Sproul Creek), so magnitude/effects of diversions likely to be variable also (that's why juvenile rank is not Very High). CDFW (2013) estimates that in years with below average rainfall, marijuana cultivation could reduce 7-day low flows by 30% in Redwood Creek and 20% in Salmon Creek. Changed rank for Egg from high to low because diversions should not substantively affect flow during incubation. No major dams.
	Bull Cr (11476600)		VG	VG																				
	Elder Cr (11475560)		VG	VG																				
	SF Eel R Accr: Miranda - Leggett (c11476500_11475800)		VG	G																				
	Eel R Accr: Scotia - Van Ars (c11477000_11471500)		VG	P																				
	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)		VG	P																				
Main Eel	population-wide	VG	VG		VG	G						H	H	H	M	H	H	L	H	VH	M	H	H	Changed rank for Egg from high to low because diversions should not substantively affect flow during incubation, and sediment from tributaries below Van Arsdale Dam (Tomki, Outlet, MF Eel, NF Eel) should provide adequate spawning gravel. Human population is low but scattered throughout the population area so diversions likely affect all tributaries with potential to provide rearing for coho salmon.
	Eel R Accr: Scotia - Ft Sew- SF Mir (c11477000_11475000_t1)		VG	F																				
	Eel R Fort Seward (11475000)		G	P																				
	Eel R Accr: Scotia - Van Ars (c11477000_11471500)		VG	P																				
	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)		VG	P																				
	Eel R Accr: Ft Sew - Van Ars - MF (c11475000_11471500_t1)		VG	P																				
	Eel R Accr: Ft Sew - DRios - MF - Outl (c11475000_11472150_t1)		VG	G																				
	Eel R Accr: Dos Rios - Van Ars (c11472150_11471500)		VG	P																				
Mid Fork Eel	population-wide	VG	VG		VG	G						L	M	M	M	M	M	L	M	M	M	M	M	
	MF Eel R (11473900)		VG	G																				
	Black Butte R (11472900)		VG	VG																				
	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)		VG	P																				
Mid Main Eel	population-wide	G	VG		VG	F						L	H	VH	H	H	H	L	H	VH	H	H	VH	Water use is extremely high in Outlet Creek relative to stream flow (i.e. 7d min flow [median value for 1981-1994] was 0.4 cfs while agricultural water use was 28.9 cfs and domestic was use was 5.6 cfs). For adult life stage, the threat rank (H) for dams and diversions is higher than the stress rank (L) for altered hydrologic function because dams block adult access to high-IP habitat in parts of Outlet Creek watershed (Morris Dam on Davis Cr, Brookstrails 3 N Dam on Willits Cr, and Lake Ada Rose on un-named trib to Willits Cr)
	Eel R Dos Rios (11472150)		F	G																				
	Outlet Cr (11472200)		G	P																				
	Eel R Accr: Scotia - Van Ars (c11477000_11471500)		VG	P																				
	Eel R Accr: Scotia - Van Ars- SF (c11477000_11471500_t1)		VG	P																				
	Eel R Accr: Ft Sew - Van Ars - MF (c11475000_11471500_t1)		VG	P																				

Life Stages Affected →		All	All	Juv	All	All	Juv	Juv	Fry	Juv	Smolt	Adult	Egg	Fry	Juv	Smolt	Adult	Over-all	Egg	Fry	Juv	Smolt	Adult	Over-all	
Data Source →		**Indicators**					**ODFW Panel**						**2012 Public Draft NMFS Plan**						**My Recommendation for Final Plan**						
Coho Population Name	**Gage or Population**	**% Coho Habitat Inaccessible**	**Reservoir volume**	**Water Use (%30-d flow)**	**Agricultural Area**	**Human Density**	**Water Management on Water Quality**	**Water Management on Habitat Access**	**Water Management on Other Factors**			**Water Management on Habitat Access**	**Dams and Diversion Threat Rank**						**Dams and Diversion Threat Rank**						**Notes**
	Eel R Accr: Dos Rios - Van Ars (c11472150_11471500)		VG	P																					
Upr Main Eel	population-wide	P	F		VG	VG							VH	VH	VH	VH	VH	VH	**VH**	**VH**	**VH**	**VH**	**VH**	**VH**	Scott Dam blocks access to 80% of high-IP habitat within the population area. So dam still has huge effect on population, even though flows have improved since 2004.
	Eel R Van Arsdale (11471500)		F	VG																					
	Eel R Scott Dam (11470500)		F	VG																					

5 RECOMMENDATIONS FOR FUTURE ANALYSES

The analyses of long-term trends in streamflow presented in this report are high-quality and statistically rigorous; however, it is difficult to determine exactly how the observed trends affect coho salmon. There is also considerable uncertainty in the estimates of human water use and comparisons of those estimates to streamflow. Some of the uncertainties and limitations are discussed above in section 2.7. Overall, I have confidence in the analyses presented in this report and the stress and threat ranks derived from them; however, as would occur during any lengthy analytical process, I encountered datasets, concepts, and tools which were outside the scope of the current project but could be beneficial to explore at a later date. Therefore, I provide the following recommendations for future analyses, which could be used to reduce uncertainty and provide additional insights:

1) Use additional methods to estimate human water diversions, and compare the results to determine a range of values.
    a. Databases are available for both California (from CDWR) and Oregon (from OWRD) for all permitted water diversions[37]. Information included in the water rights databases include: geographic location, water source, beneficial use (e.g., agriculture, domestic, etc.), and the maximum annual quantity and instantaneous rate of water that is allowed to be diverted.
    b. As noted in section 2.6.1, the U.S. census data likely undercounts human population in rural areas. Aerial photos could be used to map residences in a subset of areas to assess the accuracy of the census data. Additional datasets from individual counties such as parcel databases and assessors roles could also be used to refine population estimates.
    c. Small-scale agriculture and residential outdoor water consumption in rural areas is a substantial source of uncertainty due to lack of data. State estimate of agricultural water use focus on legal agricultural production, so do not include illegal crops or small irrigated pastures/gardens/orchards not for commercial purposes. In some areas of the ESU, these small irrigated areas could be cumulatively significant.
    d. Surveys or air photos could be used to estimate the irrigated area and water used per-household.
    e. Estimates of agricultural water use should be improved:
        i. As noted in section 2.6.2, simplistic assumption such as apportioning irrigation equally across a six-month season could be refined to be more realistic (i.e., varying by month). Additional datasets are available for agricultural water use, such as the county-level estimates for 2005 by the USGS (Kenny et al. 2009) could be compared with DWR and OWRD agricultural water use estimates. The U.S. Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) CropScape - Cropland Data Layer[38] maps the locations and acreages of crops, and these data could inputted into an agricultural water use model (see notes in section 2.6.2) to estimate agricultural water use.
        ii. For portions of the study area, local estimates of agricultural water use are available that are more accurate than the CDWR estimates. For example, Foglia et al. (2013) provide refined water use estimates for the Scott Valley.

[37] I acquired both of these datasets but did not have time to do anything with them.
[38] http://nassgeodata.gmu.edu/CropScape

2) Develop estimates of daily unimpaired hydrographs for all coho salmon populations within the SONCC ESU. Unimpaired flows should take into account complexities not addressed in this report, such as inter-basin water transfers, accounting for the effect of flow regulation by reservoirs, and mapping of specific diversions. There are a variety of methods, tools, models for developing unimpaired hydrographs and I have not investigated the details. Cooper (2002, 2004) describes some methods for developing unimpaired flows. The habitats with the highest intrinsic potential for coho salmon are not evenly distributed within each population but rather are concentrated in the low-gradient valleys where human land and water use is also concentrated. Thus, it is important that unimpaired hydrographs be developed not just near the downstream extent of each basin (i.e., where stream gages are typically located), but also at key locations throughout the basin. This would likely entail using a spatially explicit GIS-based model such as used by Deitch and Kondolf (2012) or Grantham et al. (2010).
3) Once the estimates of a daily unimpaired hydrograph are developed, they should be compared with the existing impaired daily hydrograph. Instream flow studies, for example using methods similar to those used by McBain & Trush (2012), conducted at multiple locations within the SONCC coho salmon ESU study area would be required to assess the flow requirements for various coho salmon life stages and how human alterations to the hydrograph are affecting coho salmon. Then metrics should be calculated such as the percent difference in the number of days per year between the current hydrograph and unimpaired hydrograph in which flows provide high-quality habitat for each step in the coho salmon life history (e.g., migration, spawning, and rearing).
4) During planning for this project, an additional potential indicator for assessing the threat posed by dams was developed, but there was insufficient time/budget to assess it for any populations. The indicator is "How much do dam releases mimic natural hydrograph?", with the following qualitative definitions:
    a. Poor: Dam releases do not mimic natural seasonal pattern
    b. Fair: Dam releases mimic natural seasonal pattern but flows are insufficient to maintain channel forming process
    c. Good: Dam releases mimic natural seasonal pattern and flows are sufficient to maintain channel forming process
    d. Very Good: major dams, or dam releases result in only minor alteration of hydrograph
5) Monthly water budgets should be constructed to better understand changes in hydrology over time. There are several methods for doing this, examples include Fischer et al. (1996) and Reid and Lewis (2009).
6) The accuracy of the API versus flow model that was used to remove the effect of precipitation from the long-term trend in flow would probably be increased if the APIs were applied on a daily time scale rather than the monthly time scale that was used in this report. The timing of precipitation within a month contributes additional variation/scatter to the monthly relationship. For example, a precipitation event occurring on September 30 would have a much smaller effect on average September streamflow than if it occurred on September 1. Similarly, a rain event in late September would have much more influence on October flow than a rain event in early September. The reason I applied the API versus flow model at a monthly time scale was the availability of the well-organized and easy to use monthly PRISM precipitation dataset for the entire study area. For particular watersheds of interest, individual precipitation gages may be used to construct daily API versus flow models. Another option would be to use individual precipitation gages to temporally apportion/downscale the PRISM data to a daily time step (Di Luzio et al. 2008). If a daily

model would filter out additional "noise" (relative to the monthly model used in this report), then the ability to see trends in other factors (i.e., evapotranspiration and diversions) would be enhanced and stronger conclusions could be drawn from the analysis.

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